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(54) Title: MYOCARDIAL PERFUSION IMAGING USING A<sub>2A</sub> RECEPTOR AGONISTS

(57) Abstract: A myocardial imaging method that is accomplished by administering one or more adenosine A<sub>2A</sub> adenosine receptor agonist to a human undergoing myocardial imaging.

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MYOCARDIAL PERFUSION IMAGING USING A<sub>2A</sub> RECEPTOR AGONISTS**BACKGROUND OF THE INVENTION****(1) Field of the Invention**

This invention relates to myocardial imaging methods that are accomplished by administering doses of one or more adenosine A<sub>2A</sub> adenosine receptor agonists to a mammal undergoing myocardial imaging.

**(2) Description of the Art**

Myocardial perfusion imaging (MPI) is a diagnostic technique useful for the detection and characterization of coronary artery disease. Perfusion imaging uses materials such as radionuclides to identify areas of insufficient blood flow. In MPI, blood flow is measured at rest, and the result compared with the blood flow measured during exercise on a treadmill (cardiac stress testing), such exertion being necessary to stimulate blood flow. Unfortunately, many patients are unable to exercise at levels necessary to provide sufficient blood flow, due to medical conditions such as peripheral vascular disease, arthritis, and the like.

Therefore, a pharmacological agent that increases cardiac blood flow (CBF) for a short period of time would be of great benefit, particularly one that did not cause peripheral vasodilation. Vasodilators, for example dipyridamole, have been used for this purpose in patients prior to imaging with radionuclide. Dipyridamole is an effective vasodilator, but side effects such as pain and nausea limit the usefulness of treatment with this compound.

Adenosine, a naturally occurring nucleoside, also is useful as a vasodilator. Adenosine exerts its biological effects by interacting with a family of adenosine receptors characterized as subtypes A<sub>1</sub>, A<sub>2A</sub>, A<sub>2B</sub>, and A<sub>3</sub>. Adenoscan<sup>®</sup> (Fujisawa Healthcare Inc.) is a formulation of a naturally occurring adenosine. Adenoscan<sup>®</sup> has been marketed as an adjuvant in perfusion studies using radioactive thallium-201. However, its use is limited due to side effects such as flushing, chest discomfort, the urge to breathe deeply, headache, throat, neck, and jaw pain. These adverse effects of adenosine are due to the activation of other adenosine receptor subtypes other than A<sub>2A</sub>, which mediates the vasodilatory effects of adenosine. Additionally, the short half-life of adenosine necessitates multiple treatments during the procedure, further limiting its use. Adenoscan<sup>®</sup> is contraindicated in many patients including those with second-

or third-degree block, sinus node disease, bronchoconstrictive or bronchospastic lung disease, and in patients with known hypersensitivity to the drug.

Other potent and selective agonists for the  $A_{2A}$  adenosine receptor are known. For example, MRE-0470 (Medco) is an adenosine  $A_{2A}$  receptor agonist that is a potent and selective derivative of adenosine. WRC-0470 (Medco) is an adenosine  $A_{2A}$  agonist used as an adjuvant in imaging. In general, compounds such as these have a high affinity for the  $A_{2A}$  receptor, and consequently, a long duration of action, which is undesirable in imaging.

Thus, there is still a need for a method of producing rapid and maximal coronary vasodilation in mammals without causing corresponding peripheral vasodilation, which would be useful for myocardial imaging with radionuclide agents. Preferred compounds would be selective for the  $A_{2A}$  adenosine receptor and have a short duration of action (although longer acting than compounds such as adenosine), thus obviating the need for multiple dosing.

### **SUMMARY OF THE INVENTION**

The following are several aspects of this invention.

A method of producing coronary vasodilation without peripheral vasodilation in a human, comprising administering at least 10  $\mu\text{g}$  of at least one  $A_{2A}$  receptor agonist to the human.

A method of producing coronary vasodilation without peripheral vasodilation in a human, comprising administering no more than about 1000  $\mu\text{g}$  of a  $A_{2A}$  receptor agonist to the human.

A method of producing coronary vasodilation without peripheral vasodilation in a human, comprising administering a  $A_{2A}$  receptor agonist in an amount ranging from about 10 to about 600  $\mu\text{g}$  to the human.

A method of producing coronary vasodilation without peripheral vasodilation in a human, comprising administering about 300  $\mu\text{g}$  of a  $A_{2A}$  receptor agonist to the human.

A method of producing coronary vasodilation without peripheral vasodilation in a human, comprising administering about 400  $\mu\text{g}$  of a  $A_{2A}$  receptor agonist to the human.

A method of producing coronary vasodilation without peripheral vasodilation in a human, comprising administering about 500  $\mu\text{g}$  of a  $A_{2A}$  receptor agonist to the human.

A method of producing coronary vasodilation without peripheral vasodilation in a human, comprising administering about 600  $\mu\text{g}$  of a  $A_{2A}$  receptor agonist to the human.

A method of producing coronary vasodilation without peripheral vasodilation in a human, comprising administering about 700  $\mu\text{g}$  of a  $\text{A}_{2\text{A}}$  receptor agonist to the human.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a  $\text{A}_{2\text{A}}$  receptor agonist wherein the  $\text{A}_{2\text{A}}$  receptor agonist is administered in an amount ranging from about 10 to about 600  $\mu\text{g}$  and wherein the  $\text{A}_{2\text{A}}$  receptor agonist is administered in a single dose.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a  $\text{A}_{2\text{A}}$  receptor agonist wherein about 300  $\mu\text{g}$  of the  $\text{A}_{2\text{A}}$  receptor agonist is administered in a single dose.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a  $\text{A}_{2\text{A}}$  receptor agonist wherein about 400  $\mu\text{g}$  of the  $\text{A}_{2\text{A}}$  receptor agonist is administered in a single dose.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a  $\text{A}_{2\text{A}}$  receptor agonist wherein about 500  $\mu\text{g}$  of the  $\text{A}_{2\text{A}}$  receptor agonist is administered in a single dose.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a  $\text{A}_{2\text{A}}$  receptor agonist wherein about 600  $\mu\text{g}$  of the  $\text{A}_{2\text{A}}$  receptor agonist is administered in a single dose.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a  $\text{A}_{2\text{A}}$  receptor agonist wherein about 700  $\mu\text{g}$  of the  $\text{A}_{2\text{A}}$  receptor agonist is administered in a single dose.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a  $\text{A}_{2\text{A}}$  receptor agonist wherein the  $\text{A}_{2\text{A}}$  receptor agonist is administered in an amount ranging from about 10 to about 600  $\mu\text{g}$  and wherein the  $\text{A}_{2\text{A}}$  receptor agonist is administered by iv bolus.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a  $\text{A}_{2\text{A}}$  receptor agonist wherein the  $\text{A}_{2\text{A}}$  receptor agonist is administered in an amount ranging from about 0.05 to about 60  $\mu\text{g}/\text{kg}$  and wherein the  $\text{A}_{2\text{A}}$  receptor agonist is administered by iv bolus.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a  $\text{A}_{2\text{A}}$  receptor agonist wherein the  $\text{A}_{2\text{A}}$  receptor agonist is administered in an

amount ranging from about 0.1 to about 30  $\mu\text{g/kg}$  wherein the  $A_{2A}$  receptor agonist is administered by iv bolus.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a  $A_{2A}$  receptor agonist wherein the  $A_{2A}$  receptor agonist is administered in an amount no greater than about 20  $\mu\text{g/kg}$  to a supine patient wherein the  $A_{2A}$  receptor agonist is administered by iv bolus.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a  $A_{2A}$  receptor agonist wherein the  $A_{2A}$  receptor agonist is administered in an amount no greater than about 10  $\mu\text{g/kg}$  to a standing patient wherein the  $A_{2A}$  receptor agonist is administered by iv bolus.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a  $A_{2A}$  receptor agonist wherein the  $A_{2A}$  receptor agonist is administered in an amount ranging from about 10 to about 600  $\mu\text{g}$  wherein the  $A_{2A}$  receptor agonist is administered in about 20 seconds.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a  $A_{2A}$  receptor agonist in an amount ranging from about 10 to about 600  $\mu\text{g}$  wherein the  $A_{2A}$  receptor agonist is administered in less than about 10 seconds.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a  $A_{2A}$  receptor agonist wherein the  $A_{2A}$  receptor agonist is administered in an amount greater than about 10  $\mu\text{g}$ .

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a  $A_{2A}$  receptor agonist wherein the  $A_{2A}$  receptor agonist is administered in an amount greater than about 100  $\mu\text{g}$ .

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a  $A_{2A}$  receptor agonist wherein the  $A_{2A}$  receptor agonist is administered in an amount no greater than 600  $\mu$ .

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a  $A_{2A}$  receptor agonist wherein the  $A_{2A}$  receptor agonist is administered in an amount no greater than 500  $\mu\text{g}$ .

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a  $A_{2A}$  receptor agonist wherein the  $A_{2A}$  receptor agonist is administered in an amount ranging from about 100  $\mu\text{g}$  to about 500  $\mu\text{g}$ .

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a A<sub>2A</sub> receptor agonist wherein the A<sub>2A</sub> receptor agonist is selected from the group consisting of CVT-3033, CVT-3146 and combinations thereof.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and about 300 µg of a compound selected from the group consisting of CVT-3033, CVT-3146 to the human.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and about 400 µg of a compound selected from the group consisting of CVT-3033, CVT-3146 to the human.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and about 500 µg of a compound selected from the group consisting of CVT-3033, CVT-3146 to the human.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and about 600 µg of a compound selected from the group consisting of CVT-3033, CVT-3146 to the human.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and about 700 µg of a compound selected from the group consisting of CVT-3033, CVT-3146 to the human.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a A<sub>2A</sub> receptor agonist wherein the myocardium is examined for areas of insufficient blood flow following administration of the radionuclide and the A<sub>2A</sub> receptor agonist.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a A<sub>2A</sub> receptor agonist wherein the myocardium is examined for areas of insufficient blood flow following administration of the radionuclide and the A<sub>2A</sub> receptor agonist wherein the myocardium examination begins within about 1 minute from the time the A<sub>2A</sub> receptor agonist is administered.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a A<sub>2A</sub> receptor agonist wherein the administration of the A<sub>2A</sub> receptor agonist causes at least a 2.5 fold increase in coronary blood flow.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a A<sub>2A</sub> receptor agonist wherein the administration of the A<sub>2A</sub> receptor agonist

causes at least a 2.5 fold increase in coronary blood flow that is achieved within about 1 minute from the administration of the A<sub>2A</sub> receptor agonist.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a A<sub>2A</sub> receptor agonist wherein the radionuclide and the A<sub>2A</sub> receptor agonist are administered separately.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a A<sub>2A</sub> receptor agonist wherein the radionuclide and the A<sub>2A</sub> receptor agonist are administered simultaneously.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a A<sub>2A</sub> receptor agonist wherein the administration of the A<sub>2A</sub> receptor agonist causes at least a 2.5 fold increase in coronary blood flow for less than about 5 minutes.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a A<sub>2A</sub> receptor agonist wherein the administration of the A<sub>2A</sub> receptor agonist causes at least a 2.5 fold increase in coronary blood flow for less than about 3 minutes.

A method of myocardial perfusion imaging of a human, comprising administering CVT-3146 in an amount ranging from about 10 to about 600 µg in a single iv bolus.

A method of myocardial perfusion imaging of a human, comprising administering CVT-3146 in an amount ranging from about 100 to about 500 µg in a single iv bolus.

A method of myocardial perfusion imaging of a human comprising administering CVT-3146 by iv bolus in an amount ranging from 10 to about 600 µg that is independent of the weight of the human being dosed.

In all of the methods above, the dose is preferably administered in a single dose.

In all of the methods above, at least one radionuclide is administered before, with or after the administration of the A<sub>2A</sub> receptor agonist to facilitate myocardial imaging.

In all of the methods above, the dose is preferably administered in 60 seconds or less, preferably 30 seconds or less, and more preferably 20 seconds or less.

## DESCRIPTION OF THE FIGURES

Figure 1 are intracoronary Doppler flow profiles following administration of 18 µg adenosine IC bolus (top) and 30 µg CVT-3146 IV bolus;

Figure 2 is a plot showing the relationship of the dose of CVT-3146 on coronary peak flow rates;

Figure 3 is a Table that reports the duration of time the coronary flow velocity is



greater than or equal to 2.5 times baseline coronary flow velocity for varying doses of CVT-3146 wherein “n” refers to the number of human patients dosed;

Figure 4 is a plot of the time course of the average peak velocity (APV) ratio for human patients receiving 400  $\mu$ g of CVT-3146 IV bolus;

Figure 5 is a plot of the time course of heart rate for human patients receiving 400  $\mu$ g of CVT-3146 IV bolus;

Figure 6 is the time course of blood pressure for human patients receiving 400  $\mu$ g of CVT-3146 IV bolus; and

Figure 7 is an adverse event Table.

Figure 8 is a plot of the change over time of mean CVT-3146 plasma concentration in healthy male volunteers in a supine position. The various curves relate to different amounts of CVT-3146 administered to the patients;

Figures 9 and 10 are plots of the mean change in heart rate of healthy male volunteers either in a standing position or in a supine position over time for various bolus dosing levels of CVT-3146;

Figure 11 is a plot of the maximum change in heart rate in relationship to the total dose of CVT-3146 administered to standing or supine human male patients. In the plot, the term “DBS” refers to the observed data point while “fit” refers to a curve fitted to the observed data points;

Figure 12 is a plot of heart rate – (area under curve) AUC(0-15min) of change from baseline in relationship to the total dose of CVT-3146 administered to standing or supine human subjects;

Figure 13 is a plot of the maximum change from baseline heart rate at maximum plasma concentration of CVT-3146 for patients in a supine position;

Figure 14 is a plot of heart rate – (area under the curve –time v. effect) AUCE (0-15 min) of change from baseline versus plasma AUC(0-15 min) for patients in a supine position;

Figure 15 is a plot of the time profiles of mean heart rate change from a baseline versus mean plasma concentration over time for a 20  $\mu$ g/kg dose of CVT-3146;

Figure 16 is a plot of the average peak to blood flow velocity over time following administration of CVT-3146 measured at the pulmonary artery (PA), the four limb artery (FA), brain arterial vasculature (BA) and in the left circumflex coronary artery (LCS);

Figure 17 is a plot of the percent change in heart rate (HR) and blood pressure (BP) for various doses of CVC-3146; and

Figure 18 is a plot of the change in LBF and RBF blood flow upon administering increasing amounts of ADO or CVT-3146 to awake dogs.

### DESCRIPTION OF THE INVENTION

Potent A<sub>2A</sub> agonists are useful as adjuncts in cardiac imaging when added either prior to dosing with an imaging agent or simultaneously with an imaging agent. Suitable imaging agents include <sup>201</sup>Thallium or <sup>99m</sup>Tc Sestamibi, <sup>99m</sup>Tc tetroboroxime, and <sup>99m</sup>Tc (III).

New and potent A<sub>2A</sub> agonists that increase CBF but do not significantly increase peripheral blood flow have been identified. The A<sub>2A</sub> agonists, and especially CVT-3146 and CVT-3033 have a rapid onset and a short duration when administered. An unexpected and newly identified benefit of these new compounds is that they are very useful when administered in a very small quantity in a single bolus intravenous (i.v.) injection. The A<sub>2A</sub> receptor agonists can be administered in amounts as little as 10 µg and as high as 600 µg or more and still be effective with few if any side-effects. An optimal dose may include as little as 10 µg and as much as about 1000 µg or more of a A<sub>2A</sub> receptor agonist. More preferably, an optimal dose will range from about 100 to about 500 µg of at least one A<sub>2A</sub> receptor agonist. It is preferred that the A<sub>2A</sub> receptor agonist is administered in a single bolus injection in an amount selected from about 300 µg, about 400 µg, about 500 µg, about 600 µg, and about 700 µg. These amounts are unexpectedly small when compared with adenosine which is typically administered continuously by IV infusion at a rate of about 140 µg/kg/min. Unlike adenosine, the same dosage of A<sub>2A</sub> receptor agonists, and in particular, CVT-3146 and CVT-3033 can be administered to a human patient regardless of the patient's weight. Thus, the administration of a single uniform amount of a A<sub>2A</sub> receptor agonists by iv bolus for myocardial imaging is dramatically simpler and less error prone than the time and weight dependent administration of adenosine. The dose of A<sub>2A</sub> receptor agonist administered to a human patient can, however, be determined by weight. Typically, a weight based dose will range from about 0.05 to about 60 µg/kg and more preferably from about 0.1 to about 30 µg/kg. CVT-3146 in particular is generally well tolerated when administered in an amount up to 10 µg/kg in standing patients and up to 20 µg/kg in supine patients.

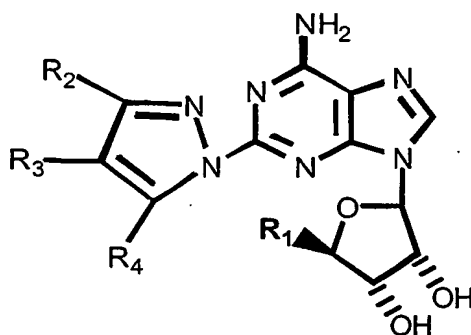
A<sub>2A</sub> agonists of this invention may be administered orally, intravenously, through the epidermis or by any other means known in the art for administering therapeutic agents with bolus i.v. administration being preferred. In one embodiment, the bolus dosing occurs in 60

seconds or less. In yet other embodiments, the bolus dosing occurs in about 30 seconds or less, and more preferably in about 20 seconds or less or in about 10 seconds or less.

The A<sub>2A</sub> agonists of this invention are preferably administered in a single dose. The term "single dose" refers generally to a single quickly administered dose of a therapeutic amount of at least one A<sub>2A</sub> receptor agonist. The term "single dose" does not encompass a dose or doses administered over an extended period of time by, for example continuous i.v. infusion.

Pharmaceutical compositions including the compounds of this invention, and/or derivatives thereof, may be formulated as solutions or lyophilized powders for parenteral administration. Powders may be reconstituted by addition of a suitable diluent or other pharmaceutically acceptable carrier prior to use. If used in liquid form the compositions of this invention are preferably incorporated into a buffered, isotonic, aqueous solution. Examples of suitable diluents are normal isotonic saline solution, standard 5% dextrose in water and buffered sodium or ammonium acetate solution. Such liquid formulations are suitable for parenteral administration, but may also be used for oral administration. It may be desirable to add excipients such as polyvinylpyrrolidone, gelatin, hydroxy cellulose, acacia, polyethylene glycol, mannitol, sodium chloride, sodium citrate or any other excipient known to one of skill in the art to pharmaceutical compositions including compounds of this invention.

A first class of compounds that are potent and selective agonists for the A<sub>2A</sub> adenosine receptor that are useful in the methods of this invention are 2-adenosine N-pyrazole compounds having the formula:



wherein R<sup>1</sup> = CH<sub>2</sub>OH, -CONR<sub>5</sub>R<sub>6</sub>;

R<sup>3</sup> is independently selected from the group consisting of C<sub>1-15</sub> alkyl, halo, NO<sub>2</sub>, CF<sub>3</sub>, CN, OR<sup>20</sup>, SR<sup>20</sup>, N(R<sup>20</sup>)<sub>2</sub>, S(O)R<sup>22</sup>, SO<sub>2</sub>R<sup>22</sup>, SO<sub>2</sub>N(R<sup>20</sup>)<sub>2</sub>, SO<sub>2</sub>NR<sup>20</sup>COR<sup>22</sup>, SO<sub>2</sub>NR<sup>20</sup>CO<sub>2</sub>R<sup>22</sup>, SO<sub>2</sub>NR<sup>20</sup>CON(R<sup>20</sup>)<sub>2</sub>, N(R<sup>20</sup>)<sub>2</sub>NR<sup>20</sup>COR<sup>22</sup>, NR<sup>20</sup>CO<sub>2</sub>R<sup>22</sup>, NR<sup>20</sup>CON(R<sup>20</sup>)<sub>2</sub>, NR<sup>20</sup>C(NR<sup>20</sup>)NHR<sup>23</sup>,

$\text{COR}^{20}$ ,  $\text{CO}_2\text{R}^{20}$ ,  $\text{CON}(\text{R}^{20})_2$ ,  $\text{CONR}^{20}\text{SO}_2\text{R}^{22}$ ,  $\text{NR}^{20}\text{SO}_2\text{R}^{22}$ ,  $\text{SO}_2\text{NR}^{20}\text{CO}_2\text{R}^{22}$ ,  $\text{OCONR}^{20}\text{SO}_2\text{R}^{22}$ ,  $\text{OC}(\text{O})\text{R}^{20}$ ,  $\text{C}(\text{O})\text{OCH}_2\text{OC}(\text{O})\text{R}^{20}$ , and  $\text{OCON}(\text{R}^{20})_2$ ,  $\text{CONR}^7\text{R}^8$ ,  $\text{C}_{2-15}$  alkenyl,  $\text{C}_{2-15}$  alkynyl, heterocyclyl, aryl, and heteroaryl, wherein the alkyl, alkenyl, alkynyl, aryl, heterocyclyl and heteroaryl substituents are optionally substituted with from 1 to 3 substituents independently selected from the group consisting of halo, alkyl,  $\text{NO}_2$ , heterocyclyl, aryl, heteroaryl,  $\text{CF}_3$ , CN,  $\text{OR}^{20}$ ,  $\text{SR}^{20}$ ,  $\text{N}(\text{R}^{20})_2$ ,  $\text{S}(\text{O})\text{R}^{22}$ ,  $\text{SO}_2\text{R}^{22}$ ,  $\text{SO}_2\text{N}(\text{R}^{20})_2$ ,  $\text{SO}_2\text{NR}^{20}\text{COR}^{22}$ ,  $\text{SO}_2\text{NR}^{20}\text{CO}_2\text{R}^{22}$ ,  $\text{SO}_2\text{NR}^{20}\text{CON}(\text{R}^{20})_2$ ,  $\text{N}(\text{R}^{20})_2\text{NR}^{20}\text{COR}^{22}$ ,  $\text{NR}^{20}\text{CO}_2\text{R}^{22}$ ,  $\text{NR}^{20}\text{CON}(\text{R}^{20})_2$ ,  $\text{NR}^{20}\text{C}(\text{NR}^{20})\text{NHR}^{23}$ ,  $\text{COR}^{20}$ ,  $\text{CO}_2\text{R}^{20}$ ,  $\text{CON}(\text{R}^{20})_2$ ,  $\text{CONR}^{20}\text{SO}_2\text{R}^{22}$ ,  $\text{NR}^{20}\text{SO}_2\text{R}^{22}$ ,  $\text{SO}_2\text{NR}^{20}\text{CO}_2\text{R}^{22}$ ,  $\text{OCONR}^{20}\text{SO}_2\text{R}^{22}$ ,  $\text{OC}(\text{O})\text{R}^{20}$ ,  $\text{C}(\text{O})\text{OCH}_2\text{OC}(\text{O})\text{R}^{20}$ , and  $\text{OCON}(\text{R}^{20})_2$  and wherein the optional substituted heteroaryl, aryl, and heterocyclyl substituents are optionally substituted with halo,  $\text{NO}_2$ , alkyl,  $\text{CF}_3$ , amino, mono- or di- alkylamino, alkyl or aryl or heteroaryl amide,  $\text{NCOR}^{22}$ ,  $\text{NR}^{20}\text{SO}_2\text{R}^{22}$ ,  $\text{COR}^{20}$ ,  $\text{CO}_2\text{R}^{20}$ ,  $\text{CON}(\text{R}^{20})_2$ ,  $\text{NR}^{20}\text{CON}(\text{R}^{20})_2$ ,  $\text{OC}(\text{O})\text{R}^{20}$ ,  $\text{OC}(\text{O})\text{N}(\text{R}^{20})_2$ ,  $\text{SR}^{20}$ ,  $\text{S}(\text{O})\text{R}^{22}$ ,  $\text{SO}_2\text{R}^{22}$ ,  $\text{SO}_2\text{N}(\text{R}^{20})_2$ , CN, or  $\text{OR}^{20}$ ;

$\text{R}^5$  and  $\text{R}^6$  are each individually selected from H, and  $\text{C}_1\text{-C}_{15}$  alkyl that is optionally substituted with from 1 to 2 substituents independently selected from the group of halo,  $\text{NO}_2$ , heterocyclyl, aryl, heteroaryl,  $\text{CF}_3$ , CN,  $\text{OR}^{20}$ ,  $\text{SR}^{20}$ ,  $\text{N}(\text{R}^{20})_2$ ,  $\text{S}(\text{O})\text{R}^{22}$ ,  $\text{SO}_2\text{R}^{22}$ ,  $\text{SO}_2\text{N}(\text{R}^{20})_2$ ,  $\text{SO}_2\text{NR}^{20}\text{COR}^{22}$ ,  $\text{SO}_2\text{NR}^{20}\text{CO}_2\text{R}^{22}$ ,  $\text{SO}_2\text{NR}^{20}\text{CON}(\text{R}^{20})_2$ ,  $\text{N}(\text{R}^{20})_2\text{NR}^{20}\text{COR}^{22}$ ,  $\text{NR}^{20}\text{CO}_2\text{R}^{22}$ ,  $\text{NR}^{20}\text{CON}(\text{R}^{20})_2$ ,  $\text{NR}^{20}\text{C}(\text{NR}^{20})\text{NHR}^{23}$ ,  $\text{COR}^{20}$ ,  $\text{CO}_2\text{R}^{20}$ ,  $\text{CON}(\text{R}^{20})_2$ ,  $\text{CONR}^{20}\text{SO}_2\text{R}^{22}$ ,  $\text{NR}^{20}\text{SO}_2\text{R}^{22}$ ,  $\text{SO}_2\text{NR}^{20}\text{CO}_2\text{R}^{22}$ ,  $\text{OCONR}^{20}\text{SO}_2\text{R}^{22}$ ,  $\text{OC}(\text{O})\text{R}^{20}$ ,  $\text{C}(\text{O})\text{OCH}_2\text{OC}(\text{O})\text{R}^{20}$ , and  $\text{OCON}(\text{R}^{20})_2$  wherein each optional substituted heteroaryl, aryl, and heterocyclyl substituent is optionally substituted with halo,  $\text{NO}_2$ , alkyl,  $\text{CF}_3$ , amino, monoalkylamino, dialkylamino, alkylamide, arylamide, heteroaryl amide,  $\text{NCOR}^{22}$ ,  $\text{NR}^{20}\text{SO}_2\text{R}^{22}$ ,  $\text{COR}^{20}$ ,  $\text{CO}_2\text{R}^{20}$ ,  $\text{CON}(\text{R}^{20})_2$ ,  $\text{NR}^{20}\text{CON}(\text{R}^{20})_2$ ,  $\text{OC}(\text{O})\text{R}^{20}$ ,  $\text{OC}(\text{O})\text{N}(\text{R}^{20})_2$ ,  $\text{SR}^{20}$ ,  $\text{S}(\text{O})\text{R}^{22}$ ,  $\text{SO}_2\text{R}^{22}$ ,  $\text{SO}_2\text{N}(\text{R}^{20})_2$ , CN, and  $\text{OR}^{20}$ ;

$\text{R}^7$  is selected from the group consisting of hydrogen,  $\text{C}_{1-15}$  alkyl,  $\text{C}_{2-15}$  alkenyl,  $\text{C}_{2-15}$  alkynyl, heterocyclyl, aryl and heteroaryl, wherein the alkyl, alkenyl, alkynyl, aryl, heterocyclyl and heteroaryl substituents are optionally substituted with from 1 to 3 substituents independently selected from the group of halo,  $\text{NO}_2$ , heterocyclyl, aryl, heteroaryl,  $\text{CF}_3$ , CN,  $\text{OR}^{20}$ ,  $\text{SR}^{20}$ ,  $\text{N}(\text{R}^{20})_2$ ,  $\text{S}(\text{O})\text{R}^{22}$ ,  $\text{SO}_2\text{R}^{22}$ ,  $\text{SO}_2\text{N}(\text{R}^{20})_2$ ,  $\text{SO}_2\text{NR}^{20}\text{COR}^{22}$ ,  $\text{SO}_2\text{NR}^{20}\text{CO}_2\text{R}^{22}$ ,  $\text{SO}_2\text{NR}^{20}\text{CON}(\text{R}^{20})_2$ ,  $\text{N}(\text{R}^{20})_2\text{NR}^{20}\text{COR}^{22}$ ,  $\text{NR}^{20}\text{CO}_2\text{R}^{22}$ ,  $\text{NR}^{20}\text{CON}(\text{R}^{20})_2$ ,  $\text{NR}^{20}\text{C}(\text{NR}^{20})\text{NHR}^{23}$ ,  $\text{COR}^{20}$ ,  $\text{CO}_2\text{R}^{20}$ ,  $\text{CON}(\text{R}^{20})_2$ ,  $\text{CONR}^{20}\text{SO}_2\text{R}^{22}$ ,  $\text{NR}^{20}\text{SO}_2\text{R}^{22}$ ,  $\text{SO}_2\text{NR}^{20}\text{CO}_2\text{R}^{22}$ ,  $\text{OCONR}^{20}\text{SO}_2\text{R}^{22}$ ,  $\text{OC}(\text{O})\text{R}^{20}$ ,  $\text{C}(\text{O})\text{OCH}_2\text{OC}(\text{O})\text{R}^{20}$  and  $\text{OCON}(\text{R}^{20})_2$  and wherein each optional substituted heteroaryl, aryl and heterocyclyl substituent is optionally substituted with halo,  $\text{NO}_2$ , alkyl,  $\text{CF}_3$ , amino, mono- or di-

alkylamino, alkyl or aryl or heteroaryl amide,  $\text{NCOR}^{22}$ ,  $\text{NR}^{20}\text{SO}_2\text{R}^{22}$ ,  $\text{COR}^{20}$ ,  $\text{CO}_2\text{R}^{20}$ ,  $\text{CON}(\text{R}^{20})_2$ ,  $\text{NR}^{20}\text{CON}(\text{R}^{20})_2$ ,  $\text{OC}(\text{O})\text{R}^{20}$ ,  $\text{OC}(\text{O})\text{N}(\text{R}^{20})_2$ ,  $\text{SR}^{20}$ ,  $\text{S}(\text{O})\text{R}^{22}$ ,  $\text{SO}_2\text{R}^{22}$ ,  $\text{SO}_2\text{N}(\text{R}^{20})_2$ ,  $\text{CN}$ , and  $\text{OR}^{20}$ ;

$\text{R}^8$  is selected from the group consisting of hydrogen,  $\text{C}_{1-15}$  alkyl,  $\text{C}_{2-15}$  alkenyl,  $\text{C}_{2-15}$  alkynyl, heterocyclyl, aryl, and heteroaryl, wherein the alkyl, alkenyl, alkynyl, aryl, heterocyclyl, and heteroaryl substituents are optionally substituted with from 1 to 3 substituents independently selected from the group consisting of halo,  $\text{NO}_2$ , heterocyclyl, aryl, heteroaryl,  $\text{CF}_3$ ,  $\text{CN}$ ,  $\text{OR}^{20}$ ,  $\text{SR}^{20}$ ,  $\text{N}(\text{R}^{20})_2$ ,  $\text{S}(\text{O})\text{R}^{22}$ ,  $\text{SO}_2\text{R}^{22}$ ,  $\text{SO}_2\text{N}(\text{R}^{20})_2$ ,  $\text{SO}_2\text{NR}^{20}\text{COR}^{22}$ ,  $\text{SO}_2\text{NR}^{20}\text{CO}_2\text{R}^{22}$ ,  $\text{SO}_2\text{NR}^{20}\text{CON}(\text{R}^{20})_2$ ,  $\text{N}(\text{R}^{20})_2\text{NR}^{20}\text{COR}^{22}$ ,  $\text{NR}^{20}\text{CO}_2\text{R}^{22}$ ,  $\text{NR}^{20}\text{CON}(\text{R}^{20})_2$ ,  $\text{NR}^{20}\text{C}(\text{NR}^{20})\text{NHR}^{23}$ ,  $\text{COR}^{20}$ ,  $\text{CO}_2\text{R}^{20}$ ,  $\text{CON}(\text{R}^{20})_2$ ,  $\text{CONR}^{20}\text{SO}_2\text{R}^{22}$ ,  $\text{NR}^{20}\text{SO}_2\text{R}^{22}$ ,  $\text{SO}_2\text{NR}^{20}\text{CO}_2\text{R}^{22}$ ,  $\text{OCONR}^{20}\text{SO}_2\text{R}^{22}$ ,  $\text{OC}(\text{O})\text{R}^{20}$ ,  $\text{C}(\text{O})\text{OCH}_2\text{OC}(\text{O})\text{R}^{20}$ , and  $\text{OCON}(\text{R}^{20})_2$  and wherein each optional substituted heteroaryl, aryl, and heterocyclyl substituent is optionally substituted with halo,  $\text{NO}_2$ , alkyl,  $\text{CF}_3$ , amino, mono- or di-alkylamino, alkyl or aryl or heteroaryl amide,  $\text{NCOR}^{22}$ ,  $\text{NR}^{20}\text{SO}_2\text{R}^{22}$ ,  $\text{COR}^{20}$ ,  $\text{CO}_2\text{R}^{20}$ ,  $\text{CON}(\text{R}^{20})_2$ ,  $\text{NR}^{20}\text{CON}(\text{R}^{20})_2$ ,  $\text{OC}(\text{O})\text{R}^{20}$ ,  $\text{OC}(\text{O})\text{N}(\text{R}^{20})_2$ ,  $\text{SR}^{20}$ ,  $\text{S}(\text{O})\text{R}^{22}$ ,  $\text{SO}_2\text{R}^{22}$ ,  $\text{SO}_2\text{N}(\text{R}^{20})_2$ ,  $\text{CN}$ , and  $\text{OR}^{20}$ ;

$\text{R}^{20}$  is selected from the group consisting of H,  $\text{C}_{1-15}$  alkyl,  $\text{C}_{2-15}$  alkenyl,  $\text{C}_{2-15}$  alkynyl, heterocyclyl, aryl, and heteroaryl, wherein the alkyl, alkenyl, alkynyl, heterocyclyl, aryl, and heteroaryl substituents are optionally substituted with from 1 to 3 substituents independently selected from halo, alkyl, mono- or dialkylamino, alkyl or aryl or heteroaryl amide,  $\text{CN}$ ,  $\text{O}-\text{C}_{1-6}$  alkyl,  $\text{CF}_3$ , aryl, and heteroaryl;

$\text{R}^{22}$  is selected from the group consisting of  $\text{C}_{1-15}$  alkyl,  $\text{C}_{2-15}$  alkenyl,  $\text{C}_{2-15}$  alkynyl, heterocyclyl, aryl, and heteroaryl, wherein the alkyl, alkenyl, alkynyl, heterocyclyl, aryl, and heteroaryl substituents are optionally substituted with from 1 to 3 substituents independently selected from halo, alkyl, mono- or dialkylamino, alkyl or aryl or heteroaryl amide,  $\text{CN}$ ,  $\text{O}-\text{C}_{1-6}$  alkyl,  $\text{CF}_3$ , aryl, and heteroaryl; and wherein  $\text{R}^2$  and  $\text{R}^4$  are selected from the group consisting of H,  $\text{C}_{1-6}$  alkyl and aryl, wherein the alkyl and aryl substituents are optionally substituted with halo,  $\text{CN}$ ,  $\text{CF}_3$ ,  $\text{OR}^{20}$  and  $\text{N}(\text{R}^{20})_2$  with the proviso that when  $\text{R}^2$  is not hydrogen then  $\text{R}^4$  is hydrogen, and when  $\text{R}^4$  is not hydrogen then  $\text{R}^2$  is hydrogen.

In an related group of compounds of this invention,  $\text{R}^3$  is selected from the group consisting of  $\text{C}_{1-15}$  alkyl, halo,  $\text{CF}_3$ ,  $\text{CN}$ ,  $\text{OR}^{20}$ ,  $\text{SR}^{20}$ ,  $\text{S}(\text{O})\text{R}^{22}$ ,  $\text{SO}_2\text{R}^{22}$ ,  $\text{SO}_2\text{N}(\text{R}^{20})_2$ ,  $\text{COR}^{20}$ ,  $\text{CO}_2\text{R}^{20}$ ,  $-\text{CONR}^7\text{R}^8$ , aryl and heteroaryl wherein the alkyl, aryl and heteroaryl substituents are optionally substituted with from 1 to 3 substituents independently selected from the group consisting of halo, aryl, heteroaryl,  $\text{CF}_3$ ,  $\text{CN}$ ,  $\text{OR}^{20}$ ,  $\text{SR}^{20}$ ,  $\text{S}(\text{O})\text{R}^{22}$ ,  $\text{SO}_2\text{R}^{22}$ ,  $\text{SO}_2\text{N}(\text{R}^{20})_2$ ,  $\text{COR}^{20}$ ,  $\text{CO}_2\text{R}^{20}$  or  $\text{CON}(\text{R}^{20})_2$ , and each optional heteroaryl and aryl substituent is optionally substituted

with halo, alkyl,  $\text{CF}_3$ , CN, and  $\text{OR}^{20}$ ;  $\text{R}^5$  and  $\text{R}^6$  are independently selected from the group of H and  $\text{C}_1\text{-C}_{15}$  alkyl including one optional aryl substituent and each optional aryl substituent that is optionally substituted with halo or  $\text{CF}_3$ ;  $\text{R}^7$  is selected from the group consisting of  $\text{C}_{1-15}$  alkyl,  $\text{C}_{2-15}$  alkynyl, aryl, and heteroaryl, wherein the alkyl, alkynyl, aryl, and heteroaryl substituents are optionally substituted with from 1 to 3 substituents independently selected from the group consisting of halo, aryl, heteroaryl,  $\text{CF}_3$ , CN,  $\text{OR}^{20}$ , and each optional heteroaryl and aryl substituent is optionally substituted with halo, alkyl,  $\text{CF}_3$ , CN, or  $\text{OR}^{20}$ ;  $\text{R}^8$  is selected from the group consisting of hydrogen and  $\text{C}_{1-15}$  alkyl;  $\text{R}^{20}$  is selected from the group consisting of H,  $\text{C}_{1-4}$  alkyl and aryl, wherein alkyl and aryl substituents are optionally substituted with one alkyl substituent; and  $\text{R}^{22}$  is selected from the group consisting of  $\text{C}_{1-4}$  alkyl and aryl which are each optionally substituted with from 1 to 3 alkyl group.

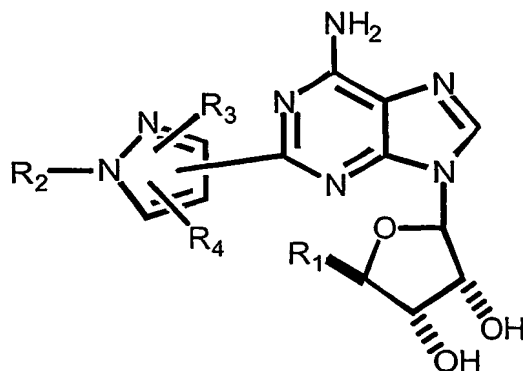
In yet another related class of compounds,  $\text{R}^1$  is  $\text{CH}_2\text{OH}$ ;  $\text{R}^3$  is selected from the group consisting of  $\text{CO}_2\text{R}^{20}$ ,  $-\text{CONR}^7\text{R}^8$  and aryl where the aryl substituent is optionally substituted with from 1 to 2 substituents independently selected from the group consisting of halo,  $\text{C}_{1-6}$  alkyl,  $\text{CF}_3$  and  $\text{OR}^{20}$ ;  $\text{R}^7$  is selected from the group consisting of hydrogen,  $\text{C}_{1-8}$  alkyl and aryl, where the alkyl and aryl substituents are optionally substituted with one substituent selected from the group consisting of halo, aryl,  $\text{CF}_3$ , CN,  $\text{OR}^{20}$  and wherein each optional aryl substituent is optionally substituted with halo, alkyl,  $\text{CF}_3$ , CN, and  $\text{OR}^{20}$ ;  $\text{R}^8$  is selected from the group consisting of hydrogen and  $\text{C}_{1-8}$  alkyl; and  $\text{R}^{20}$  is selected from hydrogen and  $\text{C}_{1-4}$  alkyl.

In a still another related class of compounds of this invention,  $\text{R}^1 = \text{CH}_2\text{OH}$ ;  $\text{R}^3$  is selected from the group consisting of  $\text{CO}_2\text{R}^{20}$ ,  $-\text{CONR}^7\text{R}^8$ , and aryl that is optionally substituted with one substituent selected from the group consisting of halo,  $\text{C}_{1-3}$  alkyl and  $\text{OR}^{20}$ ;  $\text{R}^7$  is selected from hydrogen, and  $\text{C}_{1-3}$  alkyl;  $\text{R}^8$  is hydrogen; and  $\text{R}^{20}$  is selected from hydrogen and  $\text{C}_{1-4}$  alkyl. In this preferred embodiment,  $\text{R}^3$  is most preferably selected from  $-\text{CO}_2\text{Et}$  and  $-\text{CONHET}$ .

In yet another related class of compounds,  $\text{R}^1 = -\text{CONHET}$ ,  $\text{R}^3$  is selected from the group consisting of  $\text{CO}_2\text{R}^{20}$ ,  $-\text{CONR}^7\text{R}^8$ , and aryl in that aryl is optionally substituted with from 1 to 2 substituents independently selected from the group consisting of halo,  $\text{C}_{1-3}$  alkyl,  $\text{CF}_3$  or  $\text{OR}^{20}$ ;  $\text{R}^7$  is selected from the group consisting of hydrogen, and  $\text{C}_{1-8}$  alkyl that is optionally substituted with one substituent selected from the group consisting of halo,  $\text{CF}_3$ , CN or  $\text{OR}^{20}$ ;  $\text{R}^8$  is selected from the group consisting of hydrogen and  $\text{C}_{1-3}$  alkyl; and  $\text{R}^{20}$  is selected from the group consisting of hydrogen and  $\text{C}_{1-4}$  alkyl. In this more preferred embodiment,  $\text{R}^8$  is preferably hydrogen,  $\text{R}^7$  is preferably selected from the group consisting of hydrogen, and  $\text{C}_{1-3}$ , and  $\text{R}^{20}$  is preferably selected from the group consisting of hydrogen and  $\text{C}_{1-4}$  alkyl.

Specific useful compounds are selected from ethyl 1-{9-[(4S,2R,3R,5R)-3,4-dihydroxy-5-(hydroxymethyl)oxolan-2-yl]-6-aminopurin-2-yl}pyrazole-4-carboxylate, (4S,2R,3R,5R)-2-{6-amino-2-[4-(4-chlorophenyl)pyrazolyl]purin-9-yl}-5-(hydroxymethyl)oxolane-3,4-diol, (4S,2R,3R,5R)-2-{6-amino-2-[4-(4-methoxyphenyl)pyrazolyl]purin-9-yl}-5-(hydroxymethyl)oxolane-3,4-diol, (4S,2R,3R,5R)-2-{6-amino-2-[4-(4-methylphenyl)pyrazolyl]purin-9-yl}-5-(hydroxymethyl)oxolane-3,4-diol, (1-{9-[(4S,2R,3R,5R)-3,4-dihydroxy-5-(hydroxymethyl)oxolan-2-yl]-6-aminopurin-2-yl}pyrazol-4-yl)-N-methylcarboxamide, 1-{9-[(4S,2R,3R,5R)-3,4-dihydroxy-5-(hydroxymethyl)oxolan-2-yl]-6-aminopurin-2-yl}pyrazole-4-carboxylic acid, (1-{9-[(4S,2R,3R,5R)-3,4-dihydroxy-5-(hydroxymethyl)oxolan-2-yl]-6-aminopurin-2-yl}pyrazol-4-yl)-N,N-dimethylcarboxamide, (1-{9-[(4S,2R,3R,5R)-3,4-dihydroxy-5-(hydroxymethyl)oxolan-2-yl]-6-aminopurin-2-yl}pyrazol-4-yl)-N-ethylcarboxamide, 1-{9-[(4S,2R,3R,5R)-3,4-dihydroxy-5-(hydroxymethyl)oxolan-2-yl]-6-aminopurin-2-yl}pyrazole-4-carboxamide, 1-{9-[(4S,2R,3R,5R)-3,4-dihydroxy-5-(hydroxymethyl)oxolan-2-yl]-6-aminopurin-2-yl}pyrazol-4-yl)-N-(cyclopentylmethyl)carboxamide, (1-{9-[(4S,2R,3R,5R)-3,4-dihydroxy-5-(hydroxymethyl)oxolan-2-yl]-6-aminopurin-2-yl}pyrazol-4-yl)-N-[(4-chlorophenyl)methyl]carboxamide, Ethyl 2-[(1-{9-[(4S,2R,3R,5R)-3,4-dihydroxy-5-(hydroxymethyl)oxolan-2-yl]-6-aminopurin-2-yl}pyrazol-4-yl)carbonylamino]acetate, and mixtures thereof.

A second class of compounds that are potent and selective agonists for the A<sub>2A</sub> adenosine receptor that are useful in the methods of this invention are 2-adenosine C-pyrazole compounds having the following formula:



wherein R<sup>1</sup> is -CH<sub>2</sub>OH, and -C(=O)NR<sup>5</sup>R<sup>6</sup>;

R<sup>2</sup> is selected from the group consisting of hydrogen, C<sub>1-15</sub> alkyl, C<sub>2-15</sub> alkenyl, C<sub>2-15</sub> alkynyl, heterocyclyl, aryl, and heteroaryl, wherein the alkyl, alkenyl, alkynyl, aryl, heterocyclyl,

and heteroaryl substituents are optionally substituted with from 1 to 3 substituents independently selected from the group consisting of halo, NO<sub>2</sub>, heterocyclyl, aryl, heteroaryl, CF<sub>3</sub>, CN, OR<sup>20</sup>, SR<sup>20</sup>, N(R<sup>20</sup>)<sub>2</sub>, S(O)R<sup>22</sup>, SO<sub>2</sub>R<sup>22</sup>, SO<sub>2</sub>N(R<sup>20</sup>)<sub>2</sub>, SO<sub>2</sub>NR<sup>20</sup>COR<sup>22</sup>, SO<sub>2</sub>NR<sup>20</sup>CO<sub>2</sub>R<sup>22</sup>, SO<sub>2</sub>NR<sup>20</sup>CON(R<sup>20</sup>)<sub>2</sub>, N(R<sup>20</sup>)<sub>2</sub>NR<sup>20</sup>COR<sup>22</sup>, NR<sup>20</sup>CO<sub>2</sub>R<sup>22</sup>, NR<sup>20</sup>CON(R<sup>20</sup>)<sub>2</sub>, NR<sup>20</sup>C(NR<sup>20</sup>)NHR<sup>23</sup>, COR<sup>20</sup>, CO<sub>2</sub>R<sup>20</sup>, CON(R<sup>20</sup>)<sub>2</sub>, CONR<sup>20</sup>SO<sub>2</sub>R<sup>22</sup>, NR<sup>20</sup>SO<sub>2</sub>R<sup>22</sup>, SO<sub>2</sub>NR<sup>20</sup>CO<sub>2</sub>R<sup>22</sup>, OCONR<sup>20</sup>SO<sub>2</sub>R<sup>22</sup>, OC(O)R<sup>20</sup>, C(O)OCH<sub>2</sub>OC(O)R<sup>20</sup>, and OCON(R<sup>20</sup>)<sub>2</sub> and wherein each optional heteroaryl, aryl, and heterocyclyl substituent is optionally substituted with halo, NO<sub>2</sub>, alkyl, CF<sub>3</sub>, amino, mono- or di- alkylamino, alkyl or aryl or heteroaryl amide, NCOR<sup>22</sup>, NR<sup>20</sup>SO<sub>2</sub>R<sup>22</sup>, COR<sup>20</sup>, CO<sub>2</sub>R<sup>20</sup>, CON(R<sup>20</sup>)<sub>2</sub>, NR<sup>20</sup>CON(R<sup>20</sup>)<sub>2</sub>, OC(O)R<sup>20</sup>, OC(O)N(R<sup>20</sup>)<sub>2</sub>, SR<sup>20</sup>, S(O)R<sup>22</sup>, SO<sub>2</sub>R<sup>22</sup>, SO<sub>2</sub>N(R<sup>20</sup>)<sub>2</sub>, CN, or OR<sup>20</sup>;

R<sup>3</sup>, R<sup>4</sup> are individually selected from the group consisting of hydrogen, C<sub>1-15</sub> alkyl, C<sub>2-15</sub> alkenyl, C<sub>2-15</sub> alkynyl, heterocyclyl, aryl, and heteroaryl, halo, NO<sub>2</sub>, CF<sub>3</sub>, CN, OR<sup>20</sup>, SR<sup>20</sup>, N(R<sup>20</sup>)<sub>2</sub>, S(O)R<sup>22</sup>, SO<sub>2</sub>R<sup>22</sup>, SO<sub>2</sub>N(R<sup>20</sup>)<sub>2</sub>, SO<sub>2</sub>NR<sup>20</sup>COR<sup>22</sup>, SO<sub>2</sub>NR<sup>20</sup>CO<sub>2</sub>R<sup>22</sup>, SO<sub>2</sub>NR<sup>20</sup>CON(R<sup>20</sup>)<sub>2</sub>, N(R<sup>20</sup>)<sub>2</sub>NR<sup>20</sup>COR<sup>22</sup>, NR<sup>20</sup>CO<sub>2</sub>R<sup>22</sup>, NR<sup>20</sup>CON(R<sup>20</sup>)<sub>2</sub>, NR<sup>20</sup>C(NR<sup>20</sup>)NHR<sup>23</sup>, COR<sup>20</sup>, CO<sub>2</sub>R<sup>20</sup>, CON(R<sup>20</sup>)<sub>2</sub>, CONR<sup>20</sup>SO<sub>2</sub>R<sup>22</sup>, NR<sup>20</sup>SO<sub>2</sub>R<sup>22</sup>, SO<sub>2</sub>NR<sup>20</sup>CO<sub>2</sub>R<sup>22</sup>, OCONR<sup>20</sup>SO<sub>2</sub>R<sup>22</sup>, OC(O)R<sup>20</sup>, C(O)OCH<sub>2</sub>OC(O)R<sup>20</sup>, and OCON(R<sup>20</sup>)<sub>2</sub> wherein the alkyl, alkenyl, alkynyl, aryl, heterocyclyl, and heteroaryl substituents are optionally substituted with from 1 to 3 substituents individually selected from the group consisting of halo, NO<sub>2</sub>, heterocyclyl, aryl, heteroaryl, CF<sub>3</sub>, CN, OR<sup>20</sup>, SR<sup>20</sup>, N(R<sup>20</sup>)<sub>2</sub>, S(O)R<sup>22</sup>, SO<sub>2</sub>R<sup>22</sup>, SO<sub>2</sub>N(R<sup>20</sup>)<sub>2</sub>, SO<sub>2</sub>NR<sup>20</sup>COR<sup>22</sup>, SO<sub>2</sub>NR<sup>20</sup>CO<sub>2</sub>R<sup>22</sup>, SO<sub>2</sub>NR<sup>20</sup>CON(R<sup>20</sup>)<sub>2</sub>, N(R<sup>20</sup>)<sub>2</sub>NR<sup>20</sup>COR<sup>22</sup>, NR<sup>20</sup>CO<sub>2</sub>R<sup>22</sup>, NR<sup>20</sup>CON(R<sup>20</sup>)<sub>2</sub>, NR<sup>20</sup>C(NR<sup>20</sup>)NHR<sup>23</sup>, COR<sup>20</sup>, CO<sub>2</sub>R<sup>20</sup>, CON(R<sup>20</sup>)<sub>2</sub>, CONR<sup>20</sup>SO<sub>2</sub>R<sup>22</sup>, NR<sup>20</sup>SO<sub>2</sub>R<sup>22</sup>, SO<sub>2</sub>NR<sup>20</sup>CO<sub>2</sub>R<sup>22</sup>, OCONR<sup>20</sup>SO<sub>2</sub>R<sup>22</sup>, OC(O)R<sup>20</sup>, C(O)OCH<sub>2</sub>OC(O)R<sup>20</sup>, and OCON(R<sup>20</sup>)<sub>2</sub> and wherein each optional heteroaryl, aryl, and heterocyclyl substituent is optionally substituted with halo, NO<sub>2</sub>, alkyl, CF<sub>3</sub>, amino, mono- or di- alkylamino, alkyl or aryl or heteroaryl amide, NCOR<sup>22</sup>, NR<sup>20</sup>SO<sub>2</sub>R<sup>22</sup>, COR<sup>20</sup>, CO<sub>2</sub>R<sup>20</sup>, CON(R<sup>20</sup>)<sub>2</sub>, NR<sup>20</sup>CON(R<sup>20</sup>)<sub>2</sub>, OC(O)R<sup>20</sup>, OC(O)N(R<sup>20</sup>)<sub>2</sub>, SR<sup>20</sup>, S(O)R<sup>22</sup>, SO<sub>2</sub>R<sup>22</sup>, SO<sub>2</sub>N(R<sup>20</sup>)<sub>2</sub>, CN, or OR<sup>20</sup>;

R<sup>5</sup> and R<sup>6</sup> are each individually H, C<sub>1-15</sub> alkyl with from 1 to 2 substituents independently selected from the group consisting of halo, NO<sub>2</sub>, heterocyclyl, aryl, heteroaryl, CF<sub>3</sub>, CN, OR<sup>20</sup>, SR<sup>20</sup>, N(R<sup>20</sup>)<sub>2</sub>, S(O)R<sup>22</sup>, SO<sub>2</sub>R<sup>22</sup>, SO<sub>2</sub>N(R<sup>20</sup>)<sub>2</sub>, SO<sub>2</sub>NR<sup>20</sup>COR<sup>22</sup>, SO<sub>2</sub>NR<sup>20</sup>CO<sub>2</sub>R<sup>22</sup>, SO<sub>2</sub>NR<sup>20</sup>CON(R<sup>20</sup>)<sub>2</sub>, N(R<sup>20</sup>)<sub>2</sub>NR<sup>20</sup>COR<sup>22</sup>, NR<sup>20</sup>CO<sub>2</sub>R<sup>22</sup>, NR<sup>20</sup>CON(R<sup>20</sup>)<sub>2</sub>, NR<sup>20</sup>C(NR<sup>20</sup>)NHR<sup>23</sup>, COR<sup>20</sup>, CO<sub>2</sub>R<sup>20</sup>, CON(R<sup>20</sup>)<sub>2</sub>, CONR<sup>20</sup>SO<sub>2</sub>R<sup>22</sup>, NR<sup>20</sup>SO<sub>2</sub>R<sup>22</sup>, SO<sub>2</sub>NR<sup>20</sup>CO<sub>2</sub>R<sup>22</sup>, OCONR<sup>20</sup>SO<sub>2</sub>R<sup>22</sup>, OC(O)R<sup>20</sup>, C(O)OCH<sub>2</sub>OC(O)R<sup>20</sup>, and OCON(R<sup>20</sup>)<sub>2</sub> and wherein each optional heteroaryl, aryl, and heterocyclyl substituent is optionally substituted with halo, NO<sub>2</sub>, alkyl, CF<sub>3</sub>, amino, mono- or

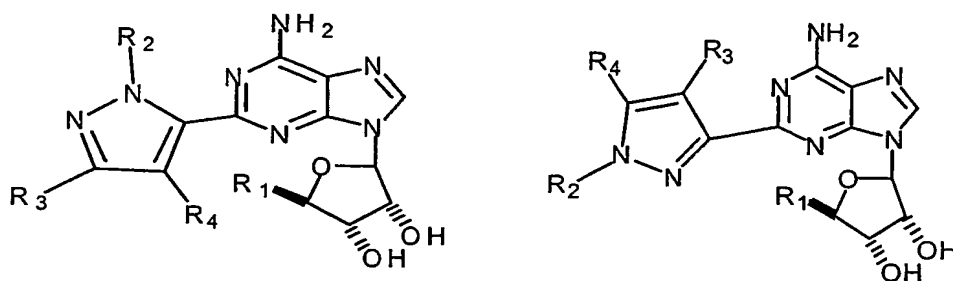


di- alkylamino, alkyl or aryl or heteroaryl amide,  $\text{NCOR}^{22}$ ,  $\text{NR}^{20}\text{SO}_2\text{R}^{22}$ ,  $\text{COR}^{20}$ ,  $\text{CO}_2\text{R}^{20}$ ,  $\text{CON}(\text{R}^{20})_2$ ,  $\text{NR}^{20}\text{CON}(\text{R}^{20})_2$ ,  $\text{OC}(\text{O})\text{R}^{20}$ ,  $\text{OC}(\text{O})\text{N}(\text{R}^{20})_2$ ,  $\text{SR}^{20}$ ,  $\text{S}(\text{O})\text{R}^{22}$ ,  $\text{SO}_2\text{R}^{22}$ ,  $\text{SO}_2\text{N}(\text{R}^{20})_2$ , CN, or  $\text{OR}^{20}$ ;

$\text{R}^{20}$  is selected from the group consisting of H,  $\text{C}_{1-15}$  alkyl,  $\text{C}_{2-15}$  alkenyl,  $\text{C}_{2-15}$  alkynyl, heterocyclyl, aryl, and heteroaryl, wherein the alkyl, alkenyl, alkynyl, heterocyclyl, aryl, and heteroaryl substituents are optionally substituted with from 1 to 3 substituents independently selected from halo, alkyl, mono- or dialkylamino, alkyl or aryl or heteroaryl amide, CN,  $\text{O-C}_{1-6}$  alkyl,  $\text{CF}_3$ , aryl, and heteroaryl; and

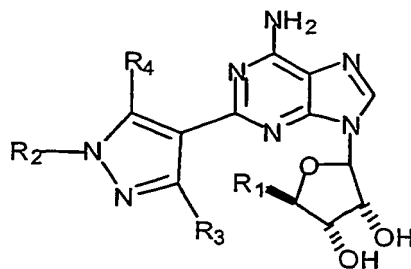
$\text{R}^{22}$  is a member selected from the group consisting of  $\text{C}_{1-15}$  alkyl,  $\text{C}_{2-15}$  alkenyl,  $\text{C}_{2-15}$  alkynyl, heterocyclyl, aryl, and heteroaryl, wherein the alkyl, alkenyl, alkynyl, heterocyclyl, aryl, and heteroaryl substituents are optionally substituted with from 1 to 3 substituents independently selected from halo, alkyl, mono- or dialkylamino, alkyl or aryl or heteroaryl amide, CN,  $\text{O-C}_{1-6}$  alkyl,  $\text{CF}_3$ , and heteroaryl wherein, when  $\text{R}^1 = \text{CH}_2\text{OH}$ ,  $\text{R}^3$  is H,  $\text{R}^4$  is H, the pyrazole ring is attached through  $\text{C}^4$ , and  $\text{R}^2$  is not H.

When the compound is selected has one of the following formulas:



then it is preferred that  $\text{R}^1$  is  $-\text{CH}_2\text{OH}$ ;  $\text{R}^2$  is selected from the group consisting of hydrogen,  $\text{C}_{1-8}$  alkyl wherein the alkyl is optionally substituted with one substituent independently selected from the group consisting of aryl,  $\text{CF}_3$ , CN, and wherein each optional aryl substituent is optionally substituted with halo, alkyl,  $\text{CF}_3$  or CN; and  $\text{R}^3$  and  $\text{R}^4$  are each independently selected from the group consisting of hydrogen, methyl and more preferably,  $\text{R}^3$  and  $\text{R}^4$  are each hydrogen.

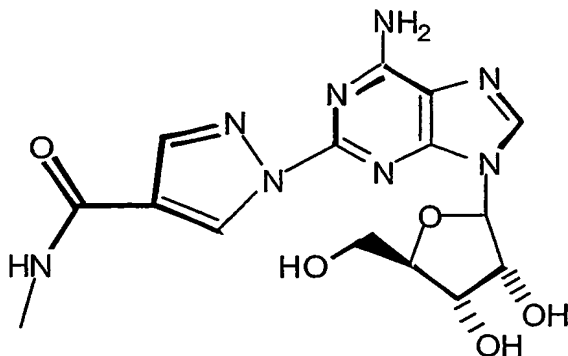
When the compound of this invention has the following formulas:



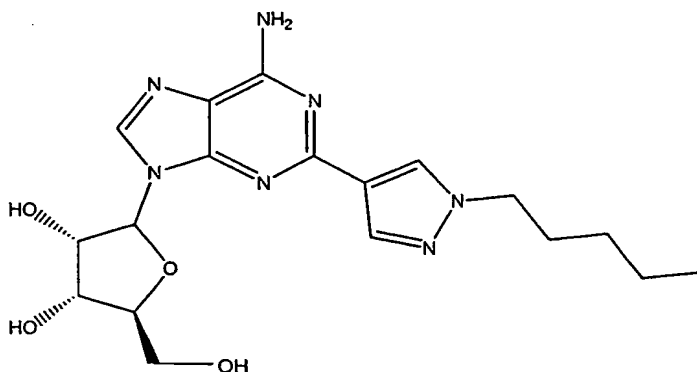
then it is preferred that  $R^1$  is  $-\text{CH}_2\text{OH}$ ;  $R^2$  is selected from the group consisting of hydrogen, and  $\text{C}_{1-6}$  alkyl optionally substituted by phenyl. More preferably,  $R^2$  is selected from benzyl and pentyl;  $R^3$  is selected from the group consisting of hydrogen,  $\text{C}_{1-6}$  alkyl, aryl, wherein the alkyl, and aryl substituents are optionally substituted with from 1 to 2 substituents independently selected from the group consisting of halo, aryl,  $\text{CF}_3$ , CN, and wherein each optional aryl substituent is optionally substituted with halo, alkyl,  $\text{CF}_3$  or CN; and  $R^4$  is selected from the group consisting of hydrogen and  $\text{C}_{1-6}$  alkyl, and more preferably,  $R^4$  is selected from hydrogen and methyl.

A more specific class of compounds is selected from the group consisting of (4S,2R,3R,5R)-2-{6-amino-2-[1-benzylpyrazol-4-yl]purin-9-yl}-5-(hydroxymethyl)oxolane-3,4-diol, (4S,2R,3R,5R)-2-[6-amino-2-(1-pentylpyrazol-4-yl)purin-9-yl]-5-(hydroxymethyl)oxolane-3,4-diol, (4S,2R,3R,5R)-2-[6-amino-2-(1-methylpyrazol-4-yl)purin-9-yl]-5-(hydroxymethyl)oxolane-3,4-diol, (4S,2R,3R,5R)-2-{6-amino-2-[1-(methylethyl)pyrazol-4-yl]purin-9-yl}-5-(hydroxymethyl)oxolane-3,4-diol, (4S,2R,3R,5R)-2-{6-amino-2-[1-(3-phenylpropyl)pyrazol-4-yl]purin-9-yl}-5-(hydroxymethyl)oxolane-3,4-diol, (4S,2R,3R,5R)-2-{6-amino-2-[1-(4-t-butylbenzyl)pyrazol-4-yl]purin-9-yl}-5-(hydroxymethyl)oxolane-3,4-diol, (4S,2R,3R,5R)-2-(6-amino-2-pyrazol-4-ylpurin-9-yl)-5-(hydroxymethyl)oxolane-3,4-diol, (4S,2R,3R,5R)-2-{6-amino-2-[1-pent-4-enylpyrazol-4-yl]purin-9-yl}-5-(hydroxymethyl)oxolane-3,4-diol, (4S,2R,3R,5R)-2-{6-amino-2-[1-decylpyrazol-4-yl]purin-9-yl}-5-(hydroxymethyl)oxolane-3,4-diol, (4S,2R,3R,5R)-2-{6-amino-2-[1-(cyclohexylmethyl)pyrazol-4-yl]purin-9-yl}-5-(hydroxymethyl)oxolane-3,4-diol, (4S,2R,3R,5R)-2-{6-amino-2-[1-(2-phenylethyl)pyrazol-4-yl]purin-9-yl}-5-(hydroxymethyl)oxolane-3,4-diol, (4S,2R,3R,5R)-2-{6-amino-2-[1-(3-cyclohexylpropyl)pyrazol-4-yl]purin-9-yl}-5-(hydroxymethyl)oxolane-3,4-diol, (4S,2R,3R,5R)-2-{6-amino-2-[1-(2-cyclohexylethyl)pyrazol-4-yl]purin-9-yl}-5-(hydroxymethyl)oxolane-3,4-diol, and combinations thereof.

A very useful and potent and selective agonists for the A<sub>2A</sub> adenosine receptor is CVT-3146 or (1-{9-[(4S,2R,3R,5R)-3,4-dihydroxy-5-(hydroxymethyl)oxolan-2-yl]-6-aminopurin-2-yl}pyrazol-4-yl)-N-methylcarboxamide which has the formula:



Another preferred compound that is useful as a selective A<sub>2A</sub>-adenosine receptor agonist with a short duration of action is a compound of the formula:



CVT-3033

CVT-3033 is particularly useful as an adjuvant in cardiological imaging.

The first and second classes of compounds identified above are described in more detail in U.S. Patent Nos. 6,403,567 and 6,214,807, the specification of each of which is incorporated herein by reference.

The following definitions apply to terms as used herein.

“Halo” or “Halogen” - alone or in combination means all halogens, that is, chloro (Cl), fluoro (F), bromo (Br), iodo (I).

“Hydroxyl” refers to the group -OH.

“Thiol” or “mercapto” refers to the group -SH.

“Alkyl” - alone or in combination means an alkane-derived radical containing from 1 to 20, preferably 1 to 15, carbon atoms (unless specifically defined). It is a straight chain

alkyl, branched alkyl or cycloalkyl. Preferably, straight or branched alkyl groups containing from 1-15, more preferably 1 to 8, even more preferably 1-6, yet more preferably 1-4 and most preferably 1-2, carbon atoms, such as methyl, ethyl, propyl, isopropyl, butyl, t-butyl and the like. The term "lower alkyl" is used herein to describe the straight chain alkyl groups described immediately above. Preferably, cycloalkyl groups are monocyclic, bicyclic or tricyclic ring systems of 3-8, more preferably 3-6, ring members per ring, such as cyclopropyl, cyclopentyl, cyclohexyl, adamantyl and the like. Alkyl also includes a straight chain or branched alkyl group that contains or is interrupted by a cycloalkyl portion. The straight chain or branched alkyl group is attached at any available point to produce a stable compound. Examples of this include, but are not limited to, 4-(isopropyl)-cyclohexylethyl or 2-methyl-cyclopropylpentyl. A substituted alkyl is a straight chain alkyl, branched alkyl, or cycloalkyl group defined previously, independently substituted with 1 to 3 groups or substituents of halo, hydroxy, alkoxy, alkylthio, alkylsulfinyl, alkylsulfonyl, acyloxy, aryloxy, heteroaryloxy, amino optionally mono- or di-substituted with alkyl, aryl or heteroaryl groups, amidino, urea optionally substituted with alkyl, aryl, heteroaryl or heterocyclyl groups, aminosulfonyl optionally N-mono- or N,N-di-substituted with alkyl, aryl or heteroaryl groups, alkylsulfonylamino, arylsulfonylamino, heteroarylsulfonylamino, alkylcarbonylamino, arylcarbonylamino, heteroarylcarbonylamino, or the like.

"Alkenyl" - alone or in combination means a straight, branched, or cyclic hydrocarbon containing 2-20, preferably 2-17, more preferably 2-10, even more preferably 2-8, most preferably 2-4, carbon atoms and at least one, preferably 1-3, more preferably 1-2, most preferably one, carbon to carbon double bond. In the case of a cycloalkyl group, conjugation of more than one carbon to carbon double bond is not such as to confer aromaticity to the ring. Carbon to carbon double bonds may be either contained within a cycloalkyl portion, with the exception of cyclopropyl, or within a straight chain or branched portion. Examples of alkenyl groups include ethenyl, propenyl, isopropenyl, butenyl, cyclohexenyl, cyclohexenylalkyl and the like. A substituted alkenyl is the straight chain alkenyl, branched alkenyl or cycloalkenyl group defined previously, independently substituted with 1 to 3 groups or substituents of halo, hydroxy, alkoxy, alkylthio, alkylsulfinyl, alkylsulfonyl, acyloxy, aryloxy, heteroaryloxy, amino optionally mono- or di-substituted with alkyl, aryl or heteroaryl groups, amidino, urea optionally substituted with alkyl, aryl, heteroaryl or heterocyclyl groups, aminosulfonyl optionally N-mono- or N,N-di-substituted with alkyl, aryl or heteroaryl groups, alkylsulfonylamino, arylsulfonylamino, heteroarylsulfonylamino, alkylcarbonylamino, arylcarbonylamino, heteroarylcarbonylamino,

carboxy, alkoxycarbonyl, aryloxy, heteroaryloxy, or the like attached at any available point to produce a stable compound.

“Alkynyl” - alone or in combination means a straight or branched hydrocarbon containing 2-20, preferably 2-17, more preferably 2-10, even more preferably 2-8, most preferably 2-4, carbon atoms containing at least one, preferably one, carbon to carbon triple bond. Examples of alkynyl groups include ethynyl, propynyl, butynyl and the like. A substituted alkynyl refers to the straight chain alkynyl or branched alkenyl defined previously, independently substituted with 1 to 3 groups or substituents of halo, hydroxy, alkoxy, alkylthio, alkylsulfinyl, alkylsulfonyl, acyloxy, aryloxy, heteroaryloxy, amino optionally mono- or di-substituted with alkyl, aryl or heteroaryl groups, amidino, urea optionally substituted with alkyl, aryl, heteroaryl or heterocyclyl groups, aminosulfonyl optionally N-mono- or N,N-di-substituted with alkyl, aryl or heteroaryl groups, alkylsulfonylamino, arylsulfonylamino, heteroarylsulfonylamino, alkylcarbonylamino, arylcarbonylamino, heteroarylcarbonylamino, or the like attached at any available point to produce a stable compound.

“Alkyl alkenyl” refers to a group  $-R-CR'=CR''R'''$ , where R is lower alkyl, or substituted lower alkyl, R', R'', R''' may independently be hydrogen, halogen, lower alkyl, substituted lower alkyl, acyl, aryl, substituted aryl, hetaryl, or substituted hetaryl as defined below.

“Alkyl alkynyl” refers to a groups  $-RC\equiv CR'$  where R is lower alkyl or substituted lower alkyl, R' is hydrogen, lower alkyl, substituted lower alkyl, acyl, aryl, substituted aryl, hetaryl, or substituted hetaryl as defined below.

“Alkoxy” denotes the group  $-OR$ , where R is lower alkyl, substituted lower alkyl, acyl, aryl, substituted aryl, aralkyl, substituted aralkyl, heteroalkyl, heteroarylalkyl, cycloalkyl, substituted cycloalkyl, cycloheteroalkyl, or substituted cycloheteroalkyl as defined.

“Alkylthio” denotes the group  $-SR$ ,  $-S(O)_{n=1-2}-R$ , where R is lower alkyl, substituted lower alkyl, aryl, substituted aryl, aralkyl or substituted aralkyl as defined herein.

“Acyl” denotes groups  $-C(O)R$ , where R is hydrogen, lower alkyl substituted lower alkyl, aryl, substituted aryl and the like as defined herein.

“Aryloxy” denotes groups  $-OAr$ , where Ar is an aryl, substituted aryl, heteroaryl, or substituted heteroaryl group as defined herein.

“Amino” denotes the group  $NRR'$ , where R and R' may independently be hydrogen, lower alkyl, substituted lower alkyl, aryl, substituted aryl, hetaryl, or substituted hetaryl as defined herein or acyl.

“Amido” denotes the group  $-C(O)NRR'$ , where R and R' may independently be hydrogen,

lower alkyl, substituted lower alkyl, aryl, substituted aryl, hetaryl, substituted hetaryl as defined herein.

“Carboxyl” denotes the group  $-C(O)OR$ , where R is hydrogen, lower alkyl, substituted lower alkyl, aryl, substituted aryl, hetaryl, and substituted hetaryl as defined herein.

“Aryl” - alone or in combination means phenyl or naphthyl optionally carbocyclic fused with a cycloalkyl of preferably 5-7, more preferably 5-6, ring members and/or optionally substituted with 1 to 3 groups or substituents of halo, hydroxy, alkoxy, alkylthio, alkylsulfinyl, alkylsulfonyl, acyloxy, aryloxy, heteroaryloxy, amino optionally mono- or di-substituted with alkyl, aryl or heteroaryl groups, amidino, urea optionally substituted with alkyl, aryl, heteroaryl or heterocyclyl groups, aminosulfonyl optionally N-mono- or N,N-di-substituted with alkyl, aryl or heteroaryl groups, alkylsulfonylamino, arylsulfonylamino, heteroarylsulfonylamino, alkylcarbonylamino, arylcarbonylamino, heteroarylcarbonylamino, or the like.

“Substituted aryl” refers to aryl optionally substituted with one or more functional groups, *e.g.*, halogen, lower alkyl, lower alkoxy, alkylthio, acetylene, amino, amido, carboxyl, hydroxyl, aryl, aryloxy, heterocycle, hetaryl, substituted hetaryl, nitro, cyano, thiol, sulfamido and the like.

“Heterocycle” refers to a saturated, unsaturated, or aromatic carbocyclic group having a single ring (*e.g.*, morpholino, pyridyl or furyl) or multiple condensed rings (*e.g.*, naphthpyridyl, quinoxalyl, quinolinyl, indolizinyl or benzo[b]thienyl) and having at least one hetero atom, such as N, O or S, within the ring, which can optionally be unsubstituted or substituted with, *e.g.*, halogen, lower alkyl, lower alkoxy, alkylthio, acetylene, amino, amido, carboxyl, hydroxyl, aryl, aryloxy, heterocycle, hetaryl, substituted hetaryl, nitro, cyano, thiol, sulfamido and the like.

“Heteroaryl” - alone or in combination means a monocyclic aromatic ring structure containing 5 or 6 ring atoms, or a bicyclic aromatic group having 8 to 10 atoms, containing one or more, preferably 1-4, more preferably 1-3, even more preferably 1-2, heteroatoms independently selected from the group O, S, and N, and optionally substituted with 1 to 3 groups or substituents of halo, hydroxy, alkoxy, alkylthio, alkylsulfinyl, alkylsulfonyl, acyloxy, aryloxy, heteroaryloxy, amino optionally mono- or di-substituted with alkyl, aryl or heteroaryl groups, amidino, urea optionally substituted with alkyl, aryl, heteroaryl or heterocyclyl groups, aminosulfonyl optionally N-mono- or N,N-di-substituted with alkyl, aryl or heteroaryl groups, alkylsulfonylamino, arylsulfonylamino, heteroarylsulfonylamino, alkylcarbonylamino, arylcarbonylamino, heteroarylcarbonylamino, or the like. Heteroaryl is also intended to include oxidized S or N, such as sulfinyl, sulfonyl and N-oxide of a tertiary ring nitrogen. A carbon or nitrogen atom is the point of attachment of the heteroaryl ring structure such that a stable aromatic ring is retained.

Examples of heteroaryl groups are pyridinyl, pyridazinyl, pyrazinyl, quinazolinyl, purinyl, indolyl, quinolinyl, pyrimidinyl, pyrrolyl, oxazolyl, thiazolyl, thienyl, isoxazolyl, oxathiadiazolyl, isothiazolyl, tetrazolyl, imidazolyl, triazinyl, furanyl, benzofuryl, indolyl and the like. A substituted heteroaryl contains a substituent attached at an available carbon or nitrogen to produce a stable compound.

"Heterocyclyl" - alone or in combination means a non-aromatic cycloalkyl group having from 5 to 10 atoms in which from 1 to 3 carbon atoms in the ring are replaced by heteroatoms of O, S or N, and are optionally benzo fused or fused heteroaryl of 5-6 ring members and/or are optionally substituted as in the case of cycloalkyl. Heterocyclyl is also intended to include oxidized S or N, such as sulfinyl, sulfonyl and N-oxide of a tertiary ring nitrogen. The point of attachment is at a carbon or nitrogen atom. Examples of heterocyclyl groups are tetrahydrofuranyl, dihydropyridinyl, piperidinyl, pyrrolidinyl, piperazinyl, dihydrobenzofuryl, dihydroindolyl, and the like. A substituted heterocyclyl contains a substituent nitrogen attached at an available carbon or nitrogen to produce a stable compound.

"Substituted heteroaryl" refers to a heterocycle optionally mono or poly substituted with one or more functional groups, *e.g.*, halogen, lower alkyl, lower alkoxy, alkylthio, acetylene, amino, amido, carboxyl, hydroxyl, aryl, aryloxy, heterocycle, substituted heterocycle, hetaryl, substituted hetaryl, nitro, cyano, thiol, sulfamido and the like.

"Aralkyl" refers to the group -R-Ar where Ar is an aryl group and R is lower alkyl or substituted lower alkyl group. Aryl groups can optionally be unsubstituted or substituted with, *e.g.*, halogen, lower alkyl, alkoxy, alkylthio, acetylene, amino, amido, carboxyl, hydroxyl, aryl, aryloxy, heterocycle, substituted heterocycle, hetaryl, substituted hetaryl, nitro, cyano, thiol, sulfamido and the like.

"Heteroalkyl" refers to the group -R-Het where Het is a heterocycle group and R is a lower alkyl group. Heteroalkyl groups can optionally be unsubstituted or substituted with *e.g.*, halogen, lower alkyl, lower alkoxy, alkylthio, acetylene, amino, amido, carboxyl, aryl, aryloxy, heterocycle, substituted heterocycle, hetaryl, substituted hetaryl, nitro, cyano, thiol, sulfamido and the like.

"Heteroarylalkyl" refers to the group -R-HetAr where HetAr is an heteroaryl group and R lower alkyl or substituted lower alkyl. Heteroarylalkyl groups can optionally be unsubstituted or substituted with, *e.g.*, halogen, lower alkyl, substituted lower alkyl, alkoxy, alkylthio, acetylene, aryl, aryloxy, heterocycle, substituted heterocycle, hetaryl, substituted hetaryl, nitro, cyano, thiol, sulfamido and the like.

"Cycloalkyl" refers to a divalent cyclic or polycyclic alkyl group containing 3 to 15 carbon

atoms.

"Substituted cycloalkyl" refers to a cycloalkyl group comprising one or more substituents with, *e.g.*, halogen, lower alkyl, substituted lower alkyl, alkoxy, alkylthio, acetylene, aryl, aryloxy, heterocycle, substituted heterocycle, hetaryl, substituted hetaryl, nitro, cyano, thiol, sulfamido and the like.

"Cycloheteroalkyl" refers to a cycloalkyl group wherein one or more of the ring carbon atoms is replaced with a heteroatom (*e.g.*, N, O, S or P).

"Substituted cycloheteroalkyl" refers to a cycloheteroalkyl group as herein defined which contains one or more substituents, such as halogen, lower alkyl, lower alkoxy, alkylthio, acetylene, amino, amido, carboxyl, hydroxyl, aryl, aryloxy, heterocycle, substituted heterocycle, hetaryl, substituted hetaryl, nitro, cyano, thiol, sulfamido and the like.

"Alkyl cycloalkyl" denotes the group -R-cycloalkyl where cycloalkyl is a cycloalkyl group and R is a lower alkyl or substituted lower alkyl. Cycloalkyl groups can optionally be unsubstituted or substituted with *e.g.* halogen, lower alkyl, lower alkoxy, alkylthio, acetylene, amino, amido, carboxyl, hydroxyl, aryl, aryloxy, heterocycle, substituted heterocycle, hetaryl, substituted hetaryl, nitro, cyano, thiol, sulfamido and the like.

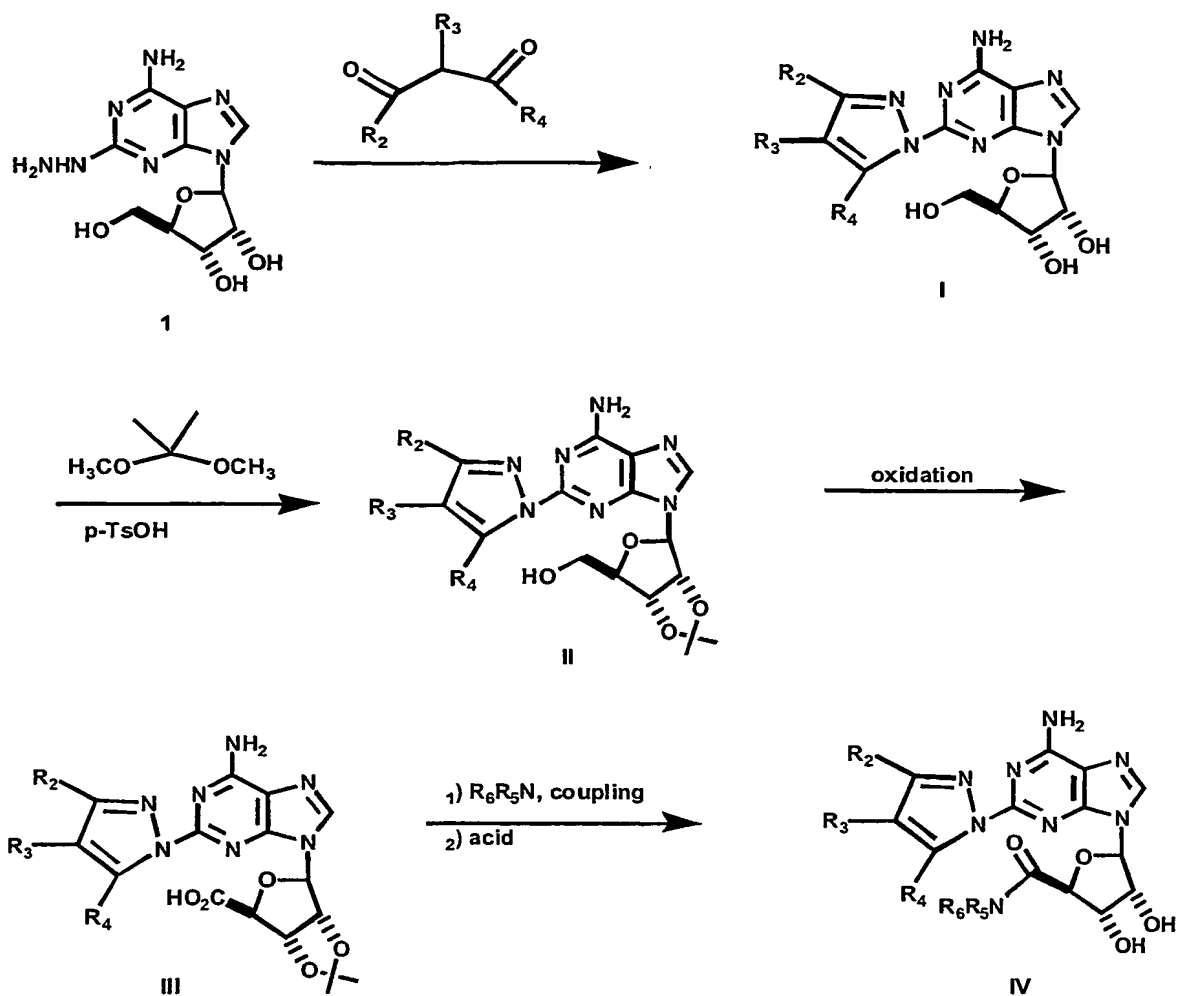
"Alkyl cycloheteroalkyl" denotes the group -R-cycloheteroalkyl where R is a lower alkyl or substituted lower alkyl. Cycloheteroalkyl groups can optionally be unsubstituted or substituted with *e.g.* halogen, lower alkyl, lower alkoxy, alkylthio, amino, amido, carboxyl, acetylene, hydroxyl, aryl, aryloxy, heterocycle, substituted heterocycle, hetaryl, substituted hetaryl, nitro, cyano, thiol, sulfamido and the like.

The first class of compounds identified above can be prepared as outlined in Schemes 1-4.

Compounds having the general formula IV can be prepared as shown in Scheme 1.

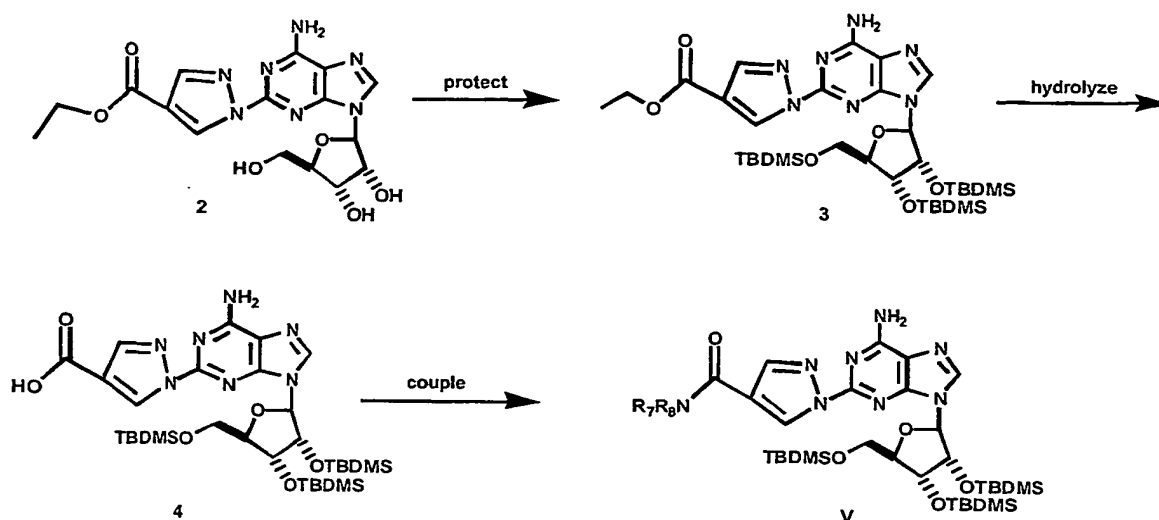


Scheme 1.



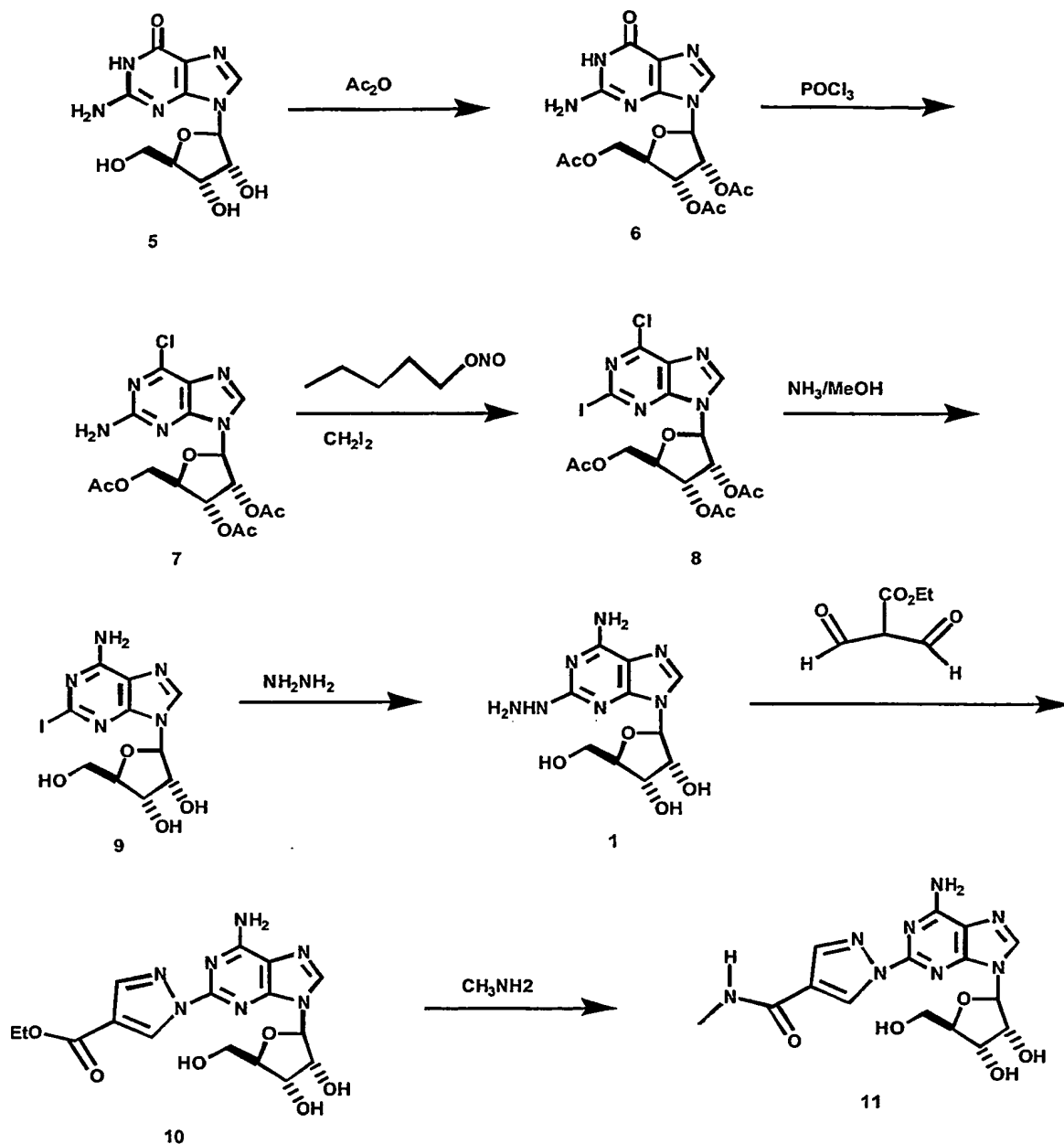
Compound I can be prepared by reacting compound 1 with appropriately substituted 1,3-dicarbonyl in a mixture of AcOH and MeOH at 80°C (Holzer et al., J. Heterocycl. Chem. (1993) 30, 865). Compound II, which can be obtained by reacting compound I with 2,2-dimethoxypropane in the presence of an acid, can be oxidized to the carboxylic acid III, based on structurally similar compounds using potassium permanganate or pyridinium chlorochromate (M. Hudlicky, (1990) Oxidations in Organic Chemistry, ACS Monographs, American Chemical Society, Washington D. C.). Reaction of a primary or secondary amine having the formula HNR<sup>6</sup>R<sup>7</sup>, and compound III using DCC (M. Fujino et al., Chem. Pharm. Bull. (1974), 22, 1857), PyBOP (J. Martinez et al., J. Med. Chem. (1988) 28, 1874) or PyBrop (J. Caste et al. Tetrahedron, (1991), 32, 1967) coupling conditions can afford compound IV.

Scheme 2.



Compound V can be prepared as shown in Scheme 2. The Tri TBDMS derivative 4 can be obtained by treating compound 2 with TBDMSCl and imidazole in DMF followed by hydrolysis of the ethyl ester using NaOH. Reaction of a primary or secondary amine with the formula  $HNR^6R^7$ , and compound 4 using DCC (M. Fujino et al., Chem. Pharm. Bull. (1974), 22, 1857), PyBOP (J. Martinez et al., J. Med. Chem. (1988) 28, 1874) or PyBrop (J. Caste et al. Tetrahedron, (1991), 32, 1967) coupling conditions can afford compound V.

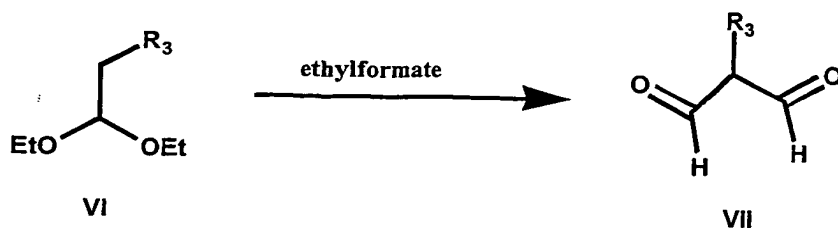
Scheme 3



A specific synthesis of Compound 11 is illustrated in Scheme 3. Commercially available guanosine 5 was converted to the triacetate 6 as previously described (M. J. Robins and B. Uznanski, *Can. J. Chem.* (1981), 59, 2601-2607). Compound 7, prepared by following the literature procedure of Cerster et al. (J. F. Cerster, A. F. Lewis, and R.K. Robins, *Org. Synthesis*, 242-243), was converted to compound 9 in two steps as previously described (V. Nair et al., *J. Org. Chem.*, (1988), 53, 3051-3057). Compound 1 was obtained by reacting hydrazine hydrate with compound 9 in ethanol at  $80^\circ\text{C}$ . Condensation of compound 1 with ethoxycarbonylmalondialdehyde in a mixture of AcOH and MeOH at  $80^\circ\text{C}$  produced

compound 10. Heating compound 10 in excess methylamine afforded compound 11.

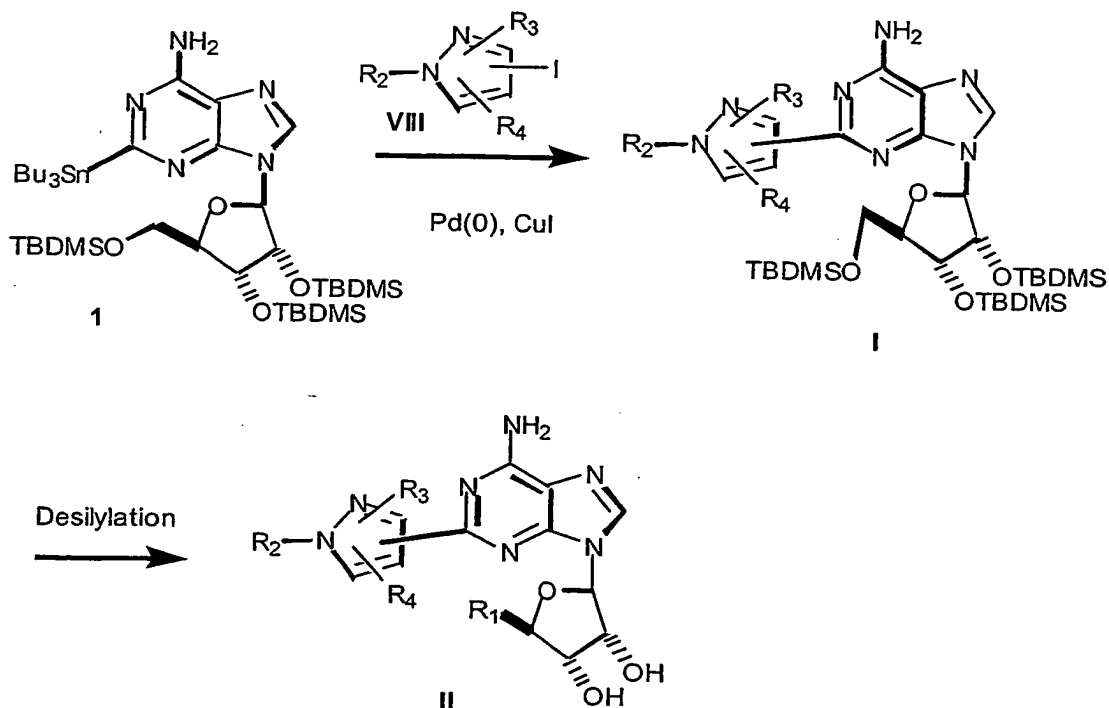
#### Scheme 4



The synthesis of 1,3-dialdehyde VII is described in Scheme 4. Reaction of 3,3-diethoxypropionate or 3,3-diethoxypropionitrile or 1,1-diethoxy-2-nitroethane VI (R<sub>3</sub> = CO<sub>2</sub>R, CN or NO<sub>2</sub>) with ethyl or methyl formate in the presence of NaH can afford the dialdehyde VII (Y. Yamamoto et al., J. Org. Chem. (1989) 54, 4734).

The second class of compound described above may be prepared by as outlined in

#### Scheme 1

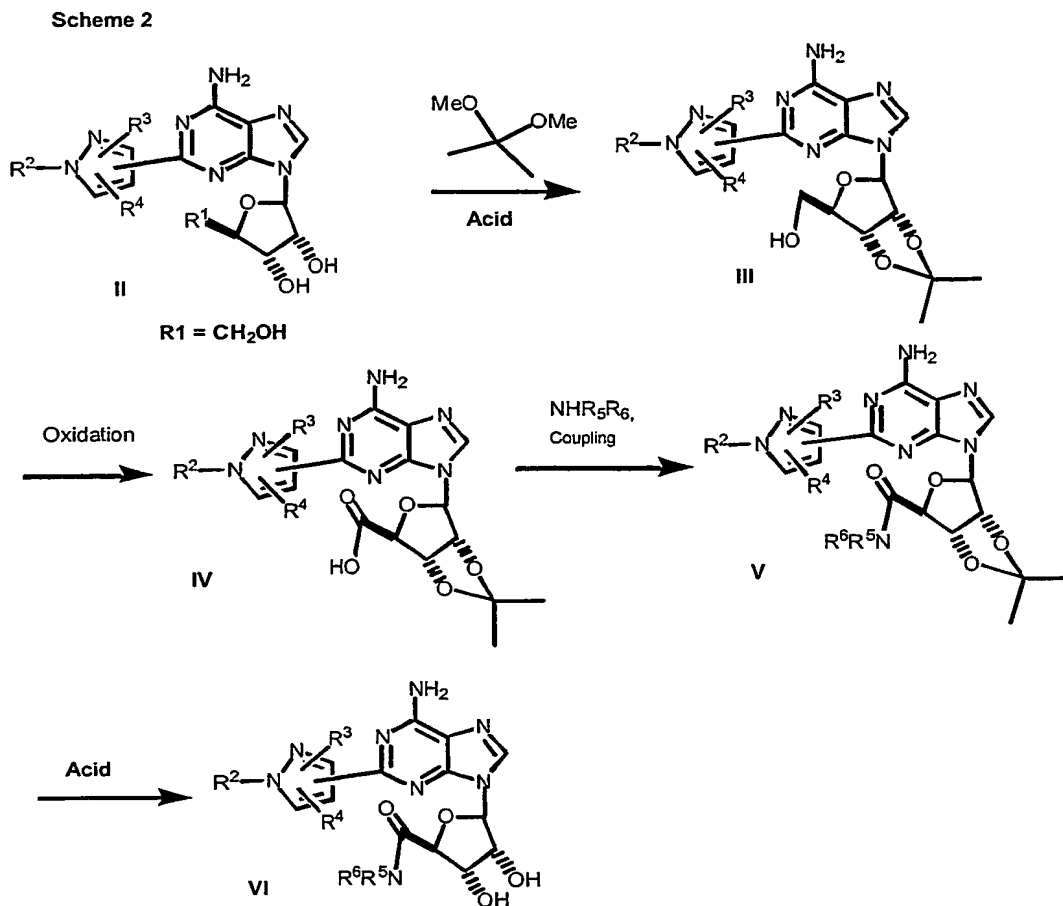


schemes 1-5. Compounds having the general formula II:

were prepared by the palladium mediated coupling of compound 1 with halo-pyrazoles represented by the formula VIII (scheme 4) in the presence or absence of copper salts (K. Kato et.

al. J. Org. Chem. 1997, 62, 6833-6841; Palladium Reagents and Catalysts-Innovations in Organic Synthesis, Tsuji, John Wiley and Sons, 1995) followed by de-protection with either TBAF or  $\text{NH}_4\text{F}$  (Markiewicz et. al Tetrahedron Lett.(1988), 29, 1561). The preparation of compound 1 has been previously described (K. Kato et. al. J. Org. Chem. 1997, 62, 6833-6841) and is outlined in scheme 5.

Compounds with general formula VI can be prepared as shown in Scheme 2. Compound III, which can be obtained by reacting II with 2,2-dimethoxypropane in presence of an

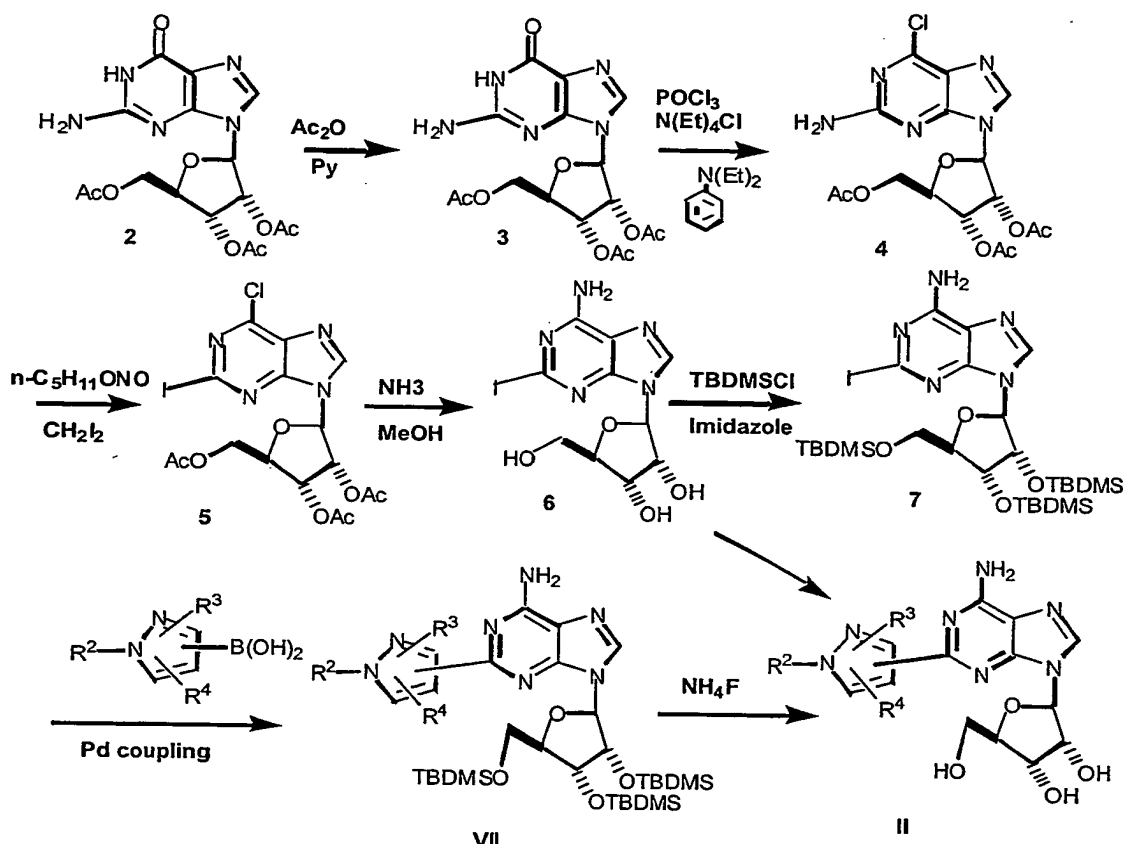


acid, can be oxidized to the carboxylic acid IV, based on structurally similar compounds, using potassium permanganate or pyridinium chlorochromate etc. ( Jones et.al., J. Am.Chem. Soc.(1949), 71, 3994.; Hudlicky, Oxidations in organic chemistry, American Chemical Society, Washington D. C., 1990) to compound IV. Reaction of primary or secondary amine of the formula  $\text{NHR}^5\text{R}^6$ , and compound IV using DCC (Fujino et.al., Chem. Pharm. Bull. (1974), 22, 1857), PyBOP (J. Martinez et. al., J. Med. Chem. (1988), 28, 1967) or PyBrop (J. Caste et.al. Tetrahedron, (1991), 32, 1967) coupling conditions can afford compound V. Deprotection of

compound V can be performed by heating with 80% aq. acetic acid (T. W. Green and P. G. M. Wuts, (1991), Protective Groups in Organic Synthesis, A, Wiley-Interscience publication) or with anhydrous HCl (4N) to obtain compound of the general formula VI.

Alternatively, compounds with the general formula II can also be prepared by Suzuki type coupling as shown in scheme 3. 2-Iodoadenosine 6 can be prepared in four steps from

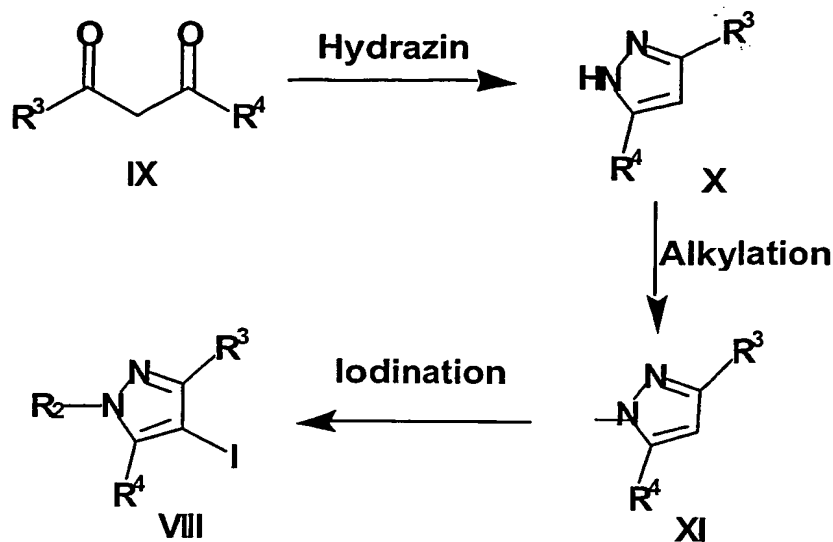
Scheme 3



guanosine 2 following literature procedures (M. J. Robins et.al. Can. J. Chem. (1981), 59, 2601-2607; J. F. Cerster et.al. Org. Synthesis, ---242-243; V. Nair et. al., J. Org. Chem., (1988), 53, 3051-3057). Palladium mediated Suzuki coupling of 6 with appropriately substituted pyrazole-boronic acids XVII in presence of a base can provide final compounds with general formula II (A.Suzuki, Acc.Chem.Res) (1982), 15, 178). If necessary, 2', 3', 5' hydroxyls on 6 can be protected as TBDMS ethers prior to Suzuki coupling.

Compounds with the general formula VIII can be either commercially available or prepared following the steps shown in scheme 4.

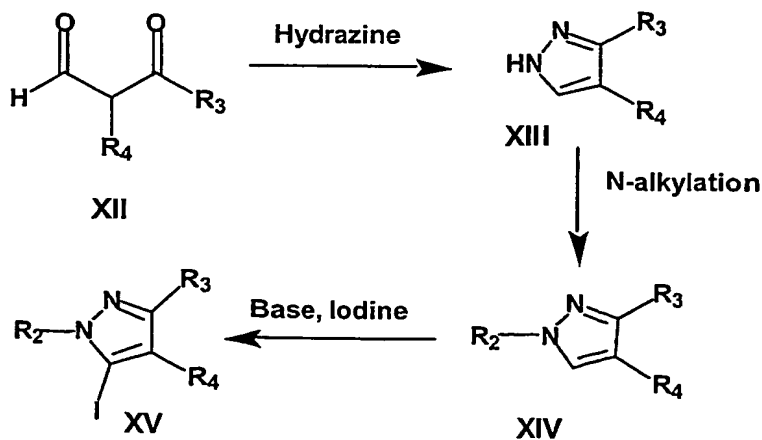
Scheme 4



Condensation of 1,3-diketone compounds of the formula IX with hydrazine in an appropriate solvent can give pyrazoles with the general formula X (R.H. Wiley et. al. Org. Synthesis, Coll. Vol IV (1963), 351). These pyrazoles can be N-alkylated with various alkyl halides to give compounds of the formula XI which on iodination give 4-iodo derivatives with the general formula VIII (R. Huttel et. al. Justus Liebigs Ann. Chem. (1955), 593, 200).

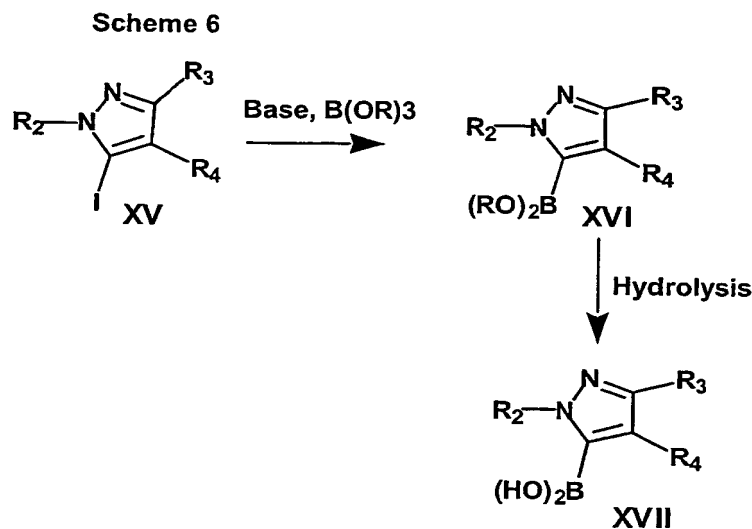
5-iodopyrazoles with the general formula XV can be prepared following the steps outlined in the scheme 5.

Scheme 5



Condensation of 1,3-diketo compounds of the formula XII with hydrazine in an appropriate solvent can give pyrazoles with the general formula XIII. These pyrazoles can be N-alkylated with various alkyl halides to give compounds of the formula XIV. Abstraction of 5-H with a strong base followed by quenching with iodine can provide 5-iodo derivatives with general formula XV (F. Effenberger et. al. J. Org. Chem. (1984), 49, 4687).

4- or 5- iodopyrazoles can be transformed into corresponding boronic acids as shown in the scheme 6. Transmetalation with n-buLi followed by treatment with trimethylborate can

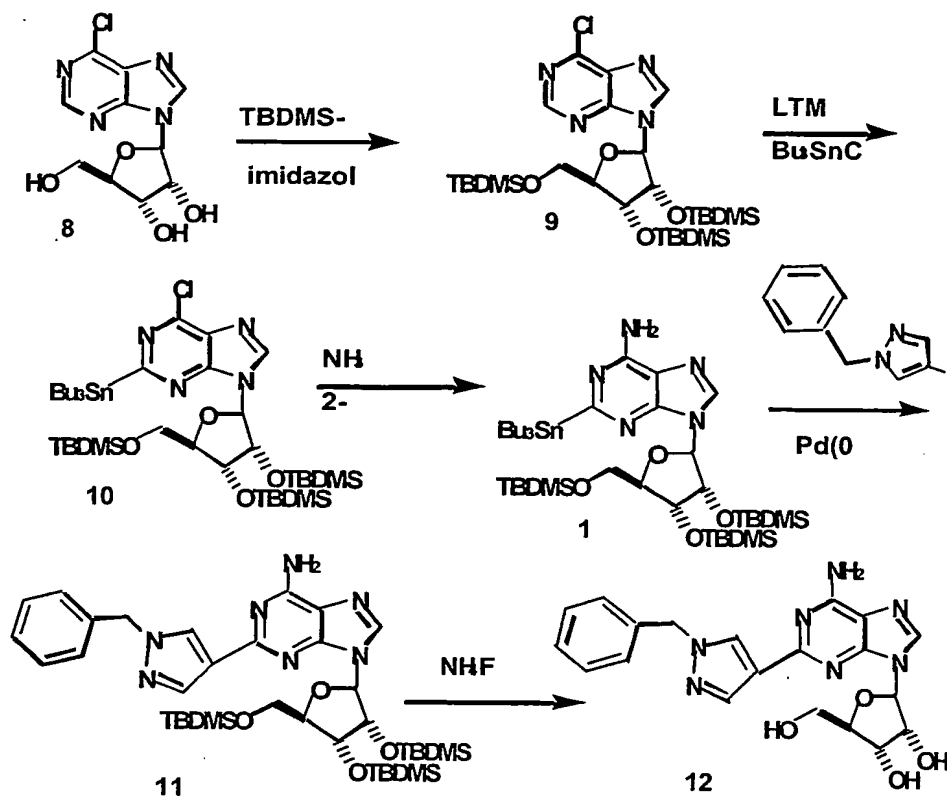


give compounds with the general formula XVI which on hydrolysis can provide boronic acids with the general formula XVII (F. C. Fischer et.al. RECUEIL (1965), 84, 439).

2-Stannyladenosine 1 was prepared in three steps from the commercially available 6-chloropurine riboside following literature procedure (K. Kato et.al., J. Org. Chem. (1997), 62, 6833-6841). Tri TBDMS derivative was obtained by treating 8 with TBDMSCl and imidazole in DMF. Lithiation with LTMP followed by quenching with tri n-butyltin chloride gave exclusively 2-stannyl derivative 10. Ammonolysis in 2-propanol gave 2-stannyladenosine 1. Stille coupling of 1 with 1-benzyl-4-iodopyrazole in presence of Pd(PPh<sub>3</sub>)<sub>4</sub> and CuI resulted in 11 (K. Kato et.al., J. Org. Chem. (1997), 62, 6833-6841). Deprotection of silyl groups on 2',3' and 5'



Scheme 7



hydroxyls with 0.5 M ammonium fluoride in methanol gave 12 in good yield (Scheme 7). The methods used to prepare the compounds of this invention are not limited to those described above. Additional methods can be found in the following sources and are included by reference (J. March, *Advanced Organic Chemistry; Reaction Mechanisms and Studies* (1992), A Wiley Interscience Publications; and J. Tsuji, *Palladium reagents and catalysts-Innovations in organic synthesis*, John Wiley and Sons, 1995).

If the final compound of this invention contains a basic group, an acid addition salt may be prepared. Acid addition salts of the compounds are prepared in a standard manner in a suitable solvent from the parent compound and an excess of acid, such as hydrochloric, hydrobromic, sulfuric, phosphoric, acetic, maleic, succinic, or methane sulfonic. The hydrochloric salt form is especially useful. If the final compound contains an acidic group, cationic salts may be prepared. Typically the parent compound is treated with an excess of an alkaline reagent, such as hydroxide, carbonate or alkoxide, containing the appropriate cation. Cations such as Na<sup>+</sup>, K<sup>+</sup>, Ca<sup>+2</sup> and NH<sub>4</sub><sup>+</sup> are examples of cations present in pharmaceutically acceptable salts. Certain of the compounds form inner salts or zwitterions which may also be acceptable.

### EXAMPLE 1

**BACKGROUND:** CVT-3146 (CVT), with an initial half-life of 3 minutes with a rapid onset and offset of action, is  $> 100$ -fold more potent than adenosine (Ado) in increasing coronary blood flow velocity (CBFv) in awake dogs. The purpose of this open label study was to determine the magnitude and duration of effect of CVT-3146 (10-500  $\mu\text{g}$ ) on CBFv in humans.

**METHODS:** Patients undergoing a clinically indicated coronary catheterization with no more than a 70% stenosis in any coronary artery and no more than a 50% stenosis of the study vessel had CBFv determined by Doppler flow wire. Study subject were selected after measuring baseline and peak CBFv after an intracoronary (IC) injection of 18  $\mu\text{g}$  of Ado. Twenty-three patients, who were identified as meeting the study criteria of having a peak to baseline CBFv ratio of  $\geq 2.5$  in response to Adenosine, received a rapid ( $\leq 10$  sec) peripheral IV bolus of CVT-3146; Doppler signals were stable and interpretable over the time-course of the increase in CBFv in 17 patients.

**RESULTS** CVT-3146 caused a rapid increase in CBFv that was near peak by 30 to 40 seconds post onset of bolus. CVT-3146 at doses of 100  $\mu\text{g}$  (n=3), 300  $\mu\text{g}$  (n=4), and 500  $\mu\text{g}$  (n=2) induced a peak to baseline ratio of  $3.2 \pm 0.6$  (mean  $\pm$  SD), similar to that obtained by IC Ado ( $3.2 \pm 0.5$ ). The duration of CBFv augmentation ( $\geq 2$ -fold increase in CBFv) was dose dependent; at 300  $\mu\text{g}$  the duration was  $4.0 \pm 4.9$  minutes and at 500  $\mu\text{g}$  was  $6.9 \pm 7.6$  minutes. At 500  $\mu\text{g}$  (n=3) the maximal increase in heart rate (HR) was  $18.7 \pm 4.0$  and the maximal decrease in systolic blood pressure (BP) was  $8.7 \pm 7.6$ . Adverse events (AEs) were infrequent and included nausea, flushing, and headache; these were mild and self-limited. No AEs were noted in the 3 patients receiving the 500  $\mu\text{g}$  dose.

**CONCLUSION:** In humans peak CBFv following CVT-3146 (IV bolus) is comparable to CBFv following IC Ado without major changes in either HR or BP. This agent's magnitude and duration of effect, adverse event profile and bolus administration make CVT-3146 a useful pharmacological stress agent for myocardial perfusion imaging.

### EXAMPLE 2

This example is a study performed to determine the range of dosages over which the selective  $A_{2A}$  receptor agonist, CVT-3146 can be administered and be effective as a coronary vasodilator.

The study included patients undergoing a clinically indicated coronary catheterization with no more than a 70% stenosis in any coronary artery and no more than a 50% stenosis of the study vessel had CBFv determined by Doppler flow wire. Study subject were selected after measuring baseline and peak CBFv after an intracoronary (IC) injection of 18  $\mu$ g of Ado. 36 subjects were identified as meeting the study criteria of having a peak to baseline CBFv ration of  $\geq 2.5$  in response to Adenosine,

CVT-3146 was administered to the study subjects by IV bolus in less that 10 seconds in amounts ranging from 10  $\mu$ g to 500  $\mu$ g.

The effectiveness of both compounds was measured by monitoring coronary flow velocity. Other coronary parameters that were monitored included heart rate and blood pressure. These parameters were measured in order to evaluate the time to peak dose response, the magnitude of the dose response and the duration of the dose response. Adverse events were also monitored. Coronary blood flow velocity was measured at the left anterior descending coronary artery (LAD) or left circumflex coronary artery (LCx). The velocity measurements were taken by following standard heart catheterization techniques and inserting a 0.014 inch Doppler-tipped Flowwire into the LAD or LCx vessel and thereafter monitoring blood flow velocity. In addition, hemodynamic and electrocardiographic measurements were recorded continuously.

Overall, 36 human subjects (n=36) were evaluated. Of the 36, 18 were female and 18 were male. Their mean age was 53.4 and they ranged from 24-72 years in age. Of the 36 subjects evaluated, the LAD vessel of 31 subjects was monitored, and the LCx vessel of 5 subjects was monitored. The following doses ( $\mu$ g) of CVT-3146 were given to the subjects in a single iv bolus: 10 (n=4); 30 (n=6); 100 (n=4); 300 (n=7); 400 (n=9); 500 (n=6).

The study results are reported in Figures 1-6. The plot of Figure 1 shows that CVT-3146 increases peak flow velocity in amounts as low as 10  $\mu$ g and reaches plateau peak velocity upon administration of less than about 100  $\mu$ g of CVT-3146. Other test results and conclusions include:

- The peak flow was reached by about 30 seconds with all doses;
- At does above about 100  $\mu$ g, peak effects were equivalent to 18  $\mu$ g adenosine administered IC;
- CVT-3146 was generally well tolerated with adverse events being reported in  
The table attached as Figure 7;

- At 400  $\mu\text{g}$ :
  - Coronary blood flow velocity  $\geq 2.5$ -fold above baseline was maintained for 2.8 minutes.
  - Maximum increase in heart rate ( $18 \pm 8$  bpm) occurs about 1 minute after dosing.
  - Maximum decrease in systolic BP ( $20 \pm 8$  mmHg) occurs about 1 minute after dosing.
  - Maximum decrease in diastolic BP ( $10 \pm 5$  mmHg) occurs about 1 minute after dosing.

### Example 3

This Example is a study performed to evaluate (1) the maximum tolerated dose of CVT-3146 and (2) the pharmacokinetic profile of CVT-3146 in healthy volunteers, after a single IV bolus dose.

#### Methods

The study was performed using thirty-six healthy, non-smoking male subjects between the ages of 18 and 59 and within 15% of ideal body weight.

#### Study design

The study was performed in phase 1, single center, double-blind, randomized, placebo-controlled, crossover, ascending dose study. Randomization was to CVT-3146 or placebo, in both supine and standing positions.

CVT-3146 was administered as an IV bolus (20 seconds) in ascending doses of 0.1, 0.3, 1.3, 10, 20 and 30  $\mu\text{g}/\text{kg}$ .

Subjects received either CVT-3146 or placebo on Day 1 supine, then crossover treatment on Day 2 supine. On Day 3, subjects received CVT-3146 or placebo standing, then crossover treatment on Day 4 standing.

#### Assessments

Patient safety was monitored by ECG, laboratory assessments, and collection of vital signs and adverse events.

#### Pharmacokinetics:

Plasma samples were drawn during supine phase (Days 1 and 2) at 0, 1, 2, 3, 4, 5, 7, 10, 15, 20, 30, 45 minutes after dosing and at 1, 1.5, 2, 4, 6, 8, 12 and 24 hours after dosing.

Urine was collected for 24 hours for CVT-3146 excretion.

## Pharmacodynamics:

- The study evaluated the relationship of changes in heart rate to dose in both standing and supine positions and plasma concentration in the supine position.

Some of the study results are reported in Figures 8-14.

## Results

## Safety

In general, adverse events reflected the pharmacologic effect of CVT-3146 and were related to vasodilation or an increase in heart rate (HR). Overall, adverse events were short-lived and mild to moderate in severity. There were no serious adverse events. Three events were assessed as severe in intensity. (Table 1).

Table 1. Adverse Events labeled as severe in intensity

Event	Number of Subjects with AE	
	20 µg/kg Standing	30 µg/kg Supine
No subjects per group	4	4
Palpitation	0	2
Dizziness	1	0
Syncope	1	0

A three-compartment open model was fit to the data using observed Tmax (1-4 minutes) as the duration of a zero-order infusion. Reliable parameter estimates were obtained for dose of 1-30 µg/kg. Parameters are summarized in the following (Table 2):

Table 2

Mean (SD) CVT-3146 Pharmacokinetic Parameters Estimated Using a Three – Compartment Model

Dose (µg/kg)	1	3	10	20	30	Total
N	3	4	4	8	3	22
CL (mL/min)	737 (106)	668 (167)	841 (120)	743 (123)	1021 (92.7)	768 (168)
Vc (L)	9.84 (4.12)	13.7 (6.06)	17.9 (6.11)	12.5 (5.83)	15.7 (4.59)	13.8 (5.67)
Vss (L)	69.0 (28.2)	90.0 (29.6)	101 (11.3)	75.2 (10.6)	89.6 (10.9)	75.5 (24.4)
α Half-life (min)	2.14 (1.38)	3.11 (2.14)	4.15 (2.75)	4.69 (4.01)	3.00 (1.05)	3.73 (2.88)
β Half-life (min)	8.93 (4.10)	17.2 (11.4)	50.2 (52.1)	32.6 (32.4)	14.0 (4.98)	27.2 (31.0)
λ Half-life (min)	99.0 (28.6)	130 (23.1)	132 (20.5)	117 (36.0)	99.4 (8.10)	86.4 (57.5)
K21 (1/min)	0.246	0.203	0.187	0.387	0.0948	0.258

	(0.255)	(0.272)	(0.305)	(0.615)	(0.0443)	(0.410)
K31 (1/min)	0.01808	0.0152	0.0108	0.0141	0.0148	0.0143
	(0.00548)	(0.00490)	(0.00592)	(0.00728)	(0.000900)	(0.00580)

CL = clearance

V<sub>c</sub> = central volume of distribution

V<sub>ss</sub> = volume of distribution at steady state

K<sub>21</sub> = the rate constant for transfer from first peripheral to central compartment

K<sub>31</sub> = rate constant for transfer from second peripheral to central compartment

## Results

- CVT-3146 was well-tolerated, with AE's mainly representing its pharmacological effects as an adenosine A<sub>2A</sub> receptor agonist.
- Mean tolerable dose for CVT-3146 was 10 µg/kg standing and 20 µg/kg supine.
- CVT-3146 does not require weight-adjusted dosing.
- There was no time lag between plasma concentration changes and changes in heart rate.
- The relationship between HR increase and dose or concentration was adequately described with a sigmoidal E<sub>max</sub> model.

## Example 4

CVT -3146 is a novel selective A<sub>2A</sub> adenosine receptor agonist being developed as a pharmacologic stressor for radionuclide myocardial perfusion imaging. Previously it has been shown that CVT -3146 causes coronary vasodilation without significantly affecting either total peripheral resistance or renal blood flow in awake dogs. The goal of this study was to determine the differential effects of CVT -3146 on blood flow velocity in various vascular beds.

The effect of CVT - 3146 was studied on the blood flow velocity in left circumflex coronary artery (LCX), brain arterial vasculature (BA), forelimb artery (FA) and pulmonary artery (PA) of comparable diameter in the anesthetized dog. CVT3146 (1.0 µg/kg) was administered as an intravenous bolus, transiently enhanced blood flow which was site specific. The effects of CVT -3146 were quantified as the average peak blood flow velocity (APV) using intravascular Doppler transducer tipped catheter. Heart rate (HR) and systemic arterial blood pressure (BP) were also monitored.

APV increased  $3.1 \pm 0.2$ ,  $1.4 \pm 0.1$ ,  $1.2 \pm 0.1$ , and  $1.1 \pm 0.01$  fold in the LCX, BA, FA and PA, respectively manifesting a site-potency rank order of LCX>>BA>FA>PA (figure 16). The effect of CVT -3146 on blood flow velocity was short lasting; reaching a peak in less than 30

sec and dissipating in less than ten minutes. Increased blood flow velocity was associated with a small transient increase in HR (16 bpm) and decrease in BP (12 mmHg). In conclusion, this study demonstrated that CVT-3146 is a potent, short lasting vasodilator that is highly selective for the coronary vasculature.

### Example 5

The present study was carried out to determine whether CVT-3146, a selective A<sub>2A</sub> adenosine receptor agonist, causes sympathoexcitation.

CVT (0.31 µg/kg-50 µg/kg) was given as a rapid i.v. bolus to awake rats and heart rate (HR) and blood pressure (BP) were monitored. CVT-3146 caused an increase in BP and systolic pressure (SP) at lower doses while at higher doses there was a decrease in BP and SP. CVT-3146 caused a dose-dependent increase in HR (Figure 17). The increase in HR was evident at the lowest dose of CVT at which there was no appreciable decrease in BP. ZM241385 (30 µg/kg, N=5), an A<sub>2A</sub> receptor antagonist, attenuated the decrease in BP (CVT-3146: 14±3%, ZM: 1±1 %) and the increase in HR (CVT: 27±3%, ZM: 18±3%) caused by CVT-3146. Pretreatment with metoprolol (MET, 1 mg/kg, n=5), a beta-blocker, attenuated the increase in HR (CVT: 27±3%, MET: 15±2%), but had no effect on hypotension caused by CVT-3146. In the presence of hexamethonium (HEX, 10 mg/kg, n=5), a ganglionic blocker, the tachycardia was prevented (CVT: 27±3%, HEX: -1±2%), but BP was further reduced (CVT: -11±2%, HEX: -49±5%). CVT-3146 (10 µg/kg, n=6) also significantly (p<0.05) increased plasma norepinephrine (control: 146±11, CVT-3146 269±22 ng/ml) and epinephrine (control: 25±5, CVT: 100±20 ng/ml) levels. The separation of HR and BP effects by dose, time and pharmacological interventions provides evidence that tachycardia caused by CVT-3146 is independent of the decrease in BP, suggesting that CVT-3146, via activation of A<sub>2A</sub> receptors may cause a direct stimulation of the sympathetic nervous system.

### Example 6

Pharmacologic stress SPECT myocardial perfusion imaging (MPI) with adenosine (A) is a well-accepted technique, with excellent diagnostic and prognostic value and proven safety. However, side effects are common and AV nodal block and severe flushing are poorly tolerated. Agents such as CVT-3146 selectively act upon the A<sub>2A</sub> adenosine receptor and avoid stimulation of other receptor subtypes which may prevent such adverse reactions.

To determine the ability of CVT-3146 to produce coronary hyperemia and accurately

detect CAD, 35 subjects (26 men, 9 women;  $67 \pm 10$  years) underwent both A and CVT-3146 stress/rest MPI, with  $10.0 \pm 9.1$  days between studies. Prior MI was noted in 12 patients, and many had prior revascularization [CABG (n=19), PCI (n=22)]. CVT-3146 [400 mcg (n=18), 500 mcg (n=17)] was administered as an IV bolus immediately followed by a saline flush, and then a Tc-99m radiopharmaceutical [sestamibi (n=34), tetrofosmin (n=1)]. SPECT images were uniformly processed, intermixed with control studies (normal and fixed-only defects), and interpreted by three observers in a blinded fashion using a 17-segment model. Quantitative analysis was also performed using 4D MSPECT. In addition to three separate readings, a consensus interpretation was performed and then a direct, same-screen comparison of A and CVT-3146 images undertaken to determine relative differences, using 5 regions per study.

The summed scores following stress were similar, both with visual (A= $13.9 \pm 1.5$ , CVT-3146= $13.2 \pm 1.3$ ; p=n.s.) and quantitative methods of analysis (A= $13.7 \pm 1.5$ , CVT-3146= $13.6 \pm 1.6$ ; p=n.s.). Similarly, comparisons between the summed rest and summed difference scores were identical. The direct comparison also revealed no differences in ischemia detection, with a regional concordance for ischemia extent and severity of 86.3% and 83.4%, respectively. No dose-dependent effect of CVT-3146 on ischemia detection was noted. A conclusion of the study is that CVT-3146, administered by a logistically simple bolus injection, provides a similar ability to detect and quantify myocardial ischemia with SPECT MPI as noted with an A infusion.

### Example 7

CVT-3146 is a selective A<sub>2A</sub> adenosine receptor agonist that produces coronary hyperemia and potentially less adverse effects due to its limited stimulation of receptor subtypes not involved with coronary vasodilation. This study evaluated the effectiveness of CVT-3146 as a pharmacologic stress agent.

36 subjects (27 men, 9 women;  $67 \pm 10$  years) were studied with two doses of CVT-3146 [400 mcg (n=18), 500 mcg (n=18)], administered as an IV bolus, as part of a pharmacologic stress myocardial perfusion imaging protocol.

Adverse effects (AE) occurred in 26 pts (72%), including chest discomfort (33%), headache (25%), and abdominal pain (11%), with a similar incidence for both doses. Flushing, dyspnea, and dizziness were more frequent in the 500-mcg group (44%, 44%, and 28%, respectively) than in the 400-mcg group (17%, 17%, and 11%, respectively). Most AEs were



mild to moderate (96%) and resolved within 15 min without treatment (91%). One serious AE occurred, with exacerbation of a migraine headache, which required hospitalization. ST and T wave abnormalities developed with CVT-3146 in 7 and 5 pts, respectively. No 2nd or 3rd degree AV block was noted and there were no serious arrhythmias. Peak hemodynamic effects are shown in Table 3 and were noted at 4 min for systolic blood pressure (BP), 8 min for diastolic BP, and within 2 min for heart rate (HR). The effect on BP was minimal and systolic BP did not fall below 90 mmHg with either dose. The mean change in HR response was higher for the 500 mcg dose (44.2%) than for 400 mcg (34.8%;  $p=n.s.$ ). Thirty min after CVT-3146, BP changes deviated  $<2\%$  from baseline but HR remained above baseline by 8.6%.

The results of this study indicate that CVT-3146 is well-tolerated and has acceptable hemodynamic effects. Minimal differences were noted in BP and HR responses between the 400 mcg and 500 mcg doses, but AEs were more frequently at the higher dose. CVT-3146 appears safe and well-tolerated for bolus-mediated pharmacologic stress perfusion imaging. Hemodynamic Changes (mean $\pm$ S.D.)

Table 3

Absolute Change	Relative Change	
Heart Rate	+21.9 $\pm$ 10.4 beats per min	+36.7% $\pm$ 21.0%
Systolic BP	-5.9 $\pm$ 10.7 mmHg	-4.1% $\pm$ 7.6%
Diastolic BP	-5.4 $\pm$ 7.2 mmHg	-7.9% $\pm$ 10.5%

### Example 8

In this study the vasodilator effects of CVT-3146 were compared to those of ADO in different vascular beds in awake dogs. Dogs were chronically instrumented for measurements of the blood flow in coronary (CBF), mesenteric (MBF), hind limb (LBF), and renal (RBF) vascular beds, and hemodynamics. Bolus injections (iv) to CVT-3146 (0.1 to 2.5  $\mu$ g/kg) and ADO (10 to 250  $\mu$ g/kg) caused significant increases in CBF (35 $\pm$ 6 to 205 $\pm$ 23% and 58 $\pm$ 13 to 163 $\pm$ 16%) and MBF (18 $\pm$ 4 to 88 $\pm$ 14% and 36 $\pm$ 8 to 84 $\pm$ 5%).

The results of the study demonstrate that CVT-3146 is a more potent and longer lasting coronary vasodilator compared to ADO (the duration for CBF above 2-fold of the baseline; CVT-3146 (2.5  $\mu$ g/kg): 130 $\pm$ 19s; ADO (250  $\mu$ g/kg): 16 $\pm$ 3s,  $P<0.5$ ). As shown in Figure 18 (mean  $\pm$  SE,  $n=6$ ), CVT-3146 caused a smaller increase in LBF than ADO. ADO caused a dose-dependent renal vasoconstriction (RBF -46 $\pm$ 7 to -85 $\pm$ 4%), whereas CVT-3146 has no or a little effect on RBF (-5 $\pm$ 2 to -11 $\pm$ 4%,  $P<0.05$ , compared to ADO). In

conclusion, CVT-3146 is a more selective and potent coronary vasodilator than ADO. CVT-3146 has no the significant effect on renal blood flow in awake dogs. These features of CVT-3146 make it an ideal candidate for radionuclide myocardial perfusion imaging.

The invention now having been fully described, it will be apparent to one of ordinary skill in the art that many changes and modifications can be made thereto without departing from the spirit or scope of the invention.

**What is claimed is:**

1. A method of producing coronary vasodilation without peripheral vasodilation comprising administering at least 10  $\mu\text{g}$  of at least one  $A_{2A}$  receptor agonist to a human.
2. The method of claim 1 wherein the  $A_{2A}$  receptor agonist is administered in an amount that does not exceed about 1000  $\mu\text{g}$ .
3. The method of claim 1 wherein the  $A_{2A}$  receptor agonist is administered in an amount ranging from about 10 to about 600  $\mu\text{g}$ .
4. The method of claim 1 wherein the  $A_{2A}$  receptor agonist is administered in a single dose.
5. The method of claim 1 wherein the  $A_{2A}$  receptor agonist is administered by iv bolus.
6. The method of claim 1 wherein the  $A_{2A}$  receptor agonist is administered in an amount ranging from about 0.05 to about 60  $\mu\text{g}/\text{kg}$  and wherein the  $A_{2A}$  receptor agonist is administered by iv bolus.
7. The method of claim 1 wherein the  $A_{2A}$  receptor agonist is administered in an amount ranging from about 0.1 to about 30  $\mu\text{g}/\text{kg}$  wherein the  $A_{2A}$  receptor agonist is administered by iv bolus.
8. The method of claim 1 wherein the  $A_{2A}$  receptor agonist is administered in an amount no greater than about 20  $\mu\text{g}/\text{kg}$  to a supine patient and wherein the  $A_{2A}$  receptor agonist is administered by iv bolus.
9. The method of claim 1 wherein the  $A_{2A}$  receptor agonist is administered in an amount no greater than about 10  $\mu\text{g}/\text{kg}$  to a standing patient wherein the  $A_{2A}$  receptor agonist is administered by iv bolus.
10. The method of claim 1 wherein the  $A_{2A}$  receptor agonist is administered in an amount ranging from about 10 to about 600  $\mu\text{g}$  wherein the wherein the  $A_{2A}$  receptor agonist is administered in about 20 seconds.
11. The method of claim 1 wherein the  $A_{2A}$  receptor agonist is administered in an amount ranging from about 10 to about 600  $\mu\text{g}$  wherein the  $A_{2A}$  receptor agonist is administered in less than about 10 seconds.

12. The method of claim 1 wherein the A<sub>2A</sub> receptor agonist is administered in an amount greater than about 100 µg.
13. The method of claim 1 wherein the A<sub>2A</sub> receptor agonist is administered in an amount no greater than 600 µ.
14. The method of claim 1 wherein the A<sub>2A</sub> receptor agonist is administered in an amount no greater than 500 µg.
15. The method of claim 1 wherein the A<sub>2A</sub> receptor agonist is administered in an amount ranging from about 100 µg to about 500 µg.
16. The method of claim 1 wherein the A<sub>2A</sub> receptor agonist is selected from the group consisting of CVT-3033, CVT-3146 and combinations thereof.
17. A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a A<sub>2A</sub> receptor agonist to the human wherein the myocardium is examined for areas of insufficient blood flow following administration of the radionuclide and the A<sub>2A</sub> receptor agonist.
18. The method of claim 17 wherein the myocardium examination begins within about 1 minute from the time the A<sub>2A</sub> receptor agonist is administered.
19. The method of claim 17 wherein the administration of the A<sub>2A</sub> receptor agonist causes at least a 2.5 fold increase in coronary blood flow.
20. The method of claim 17 wherein the administration of the A<sub>2A</sub> receptor agonist causes at least a 2.5 fold increase in coronary blood flow that is achieved within about 1 minute from the administration of the A<sub>2A</sub> receptor agonist.
21. The method of claim 17 wherein the radionuclide and the A<sub>2A</sub> receptor agonist are administered separately.
22. The method of claim 17 wherein the radionuclide and the A<sub>2A</sub> receptor agonist are administered simultaneously.
23. The method of claim 17 wherein the administration of the A<sub>2A</sub> receptor agonist causes at least a 2.5 fold increase in coronary blood flow for less than about 5 minutes.
24. The method of claim 17 wherein the administration of the A<sub>2A</sub> receptor agonist causes at least a 2.5 fold increase in coronary blood flow for less than about 3 minutes.
25. The method of claim 17 wherein the A<sub>2A</sub> receptor agonist is CVT-3146 which is administered in an amount ranging from about 10 to about 600 µg in a single iv bolus.

26. The method of claim 25 wherein CVT-3146 is administered in an amount ranging from about 100 to about 500  $\mu\text{g}$  in a single iv bolus.

27. The method of claim 17 wherein the a  $A_{2A}$  receptor agonist is CVT-3146 which is administered in a single dose in an amount ranging from 10 to about 600  $\mu\text{g}$  that is independent of the weight of the human being dosed.

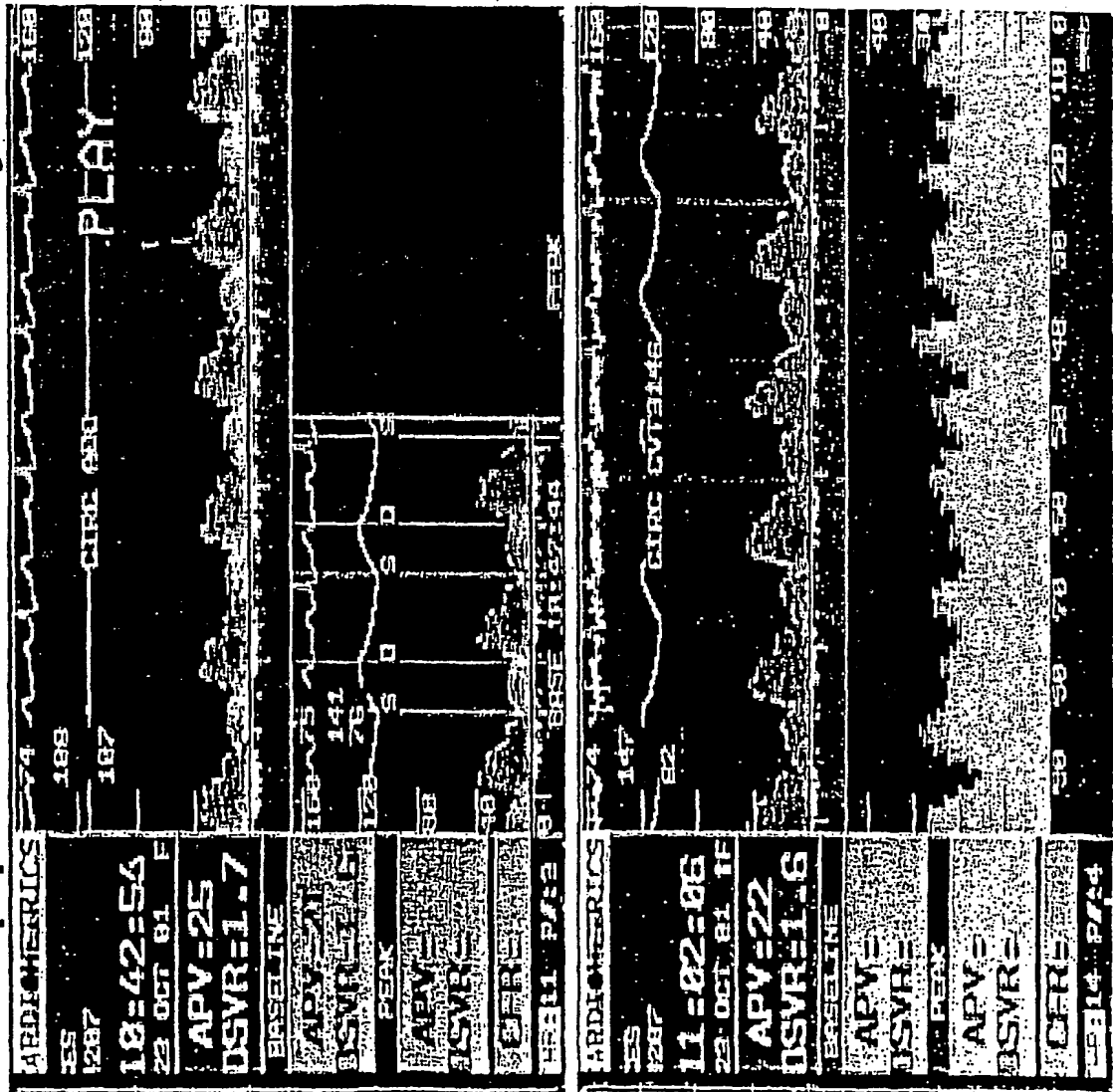
28. The method of claim 27 wherein the dose is administered in about 30 seconds or less.

29. The method of claim 27 wherein the dose is administered in about 20 seconds or less.

30. The method of claim 17 wherein the  $A_{2A}$  receptor agonist is administered in a single dose.

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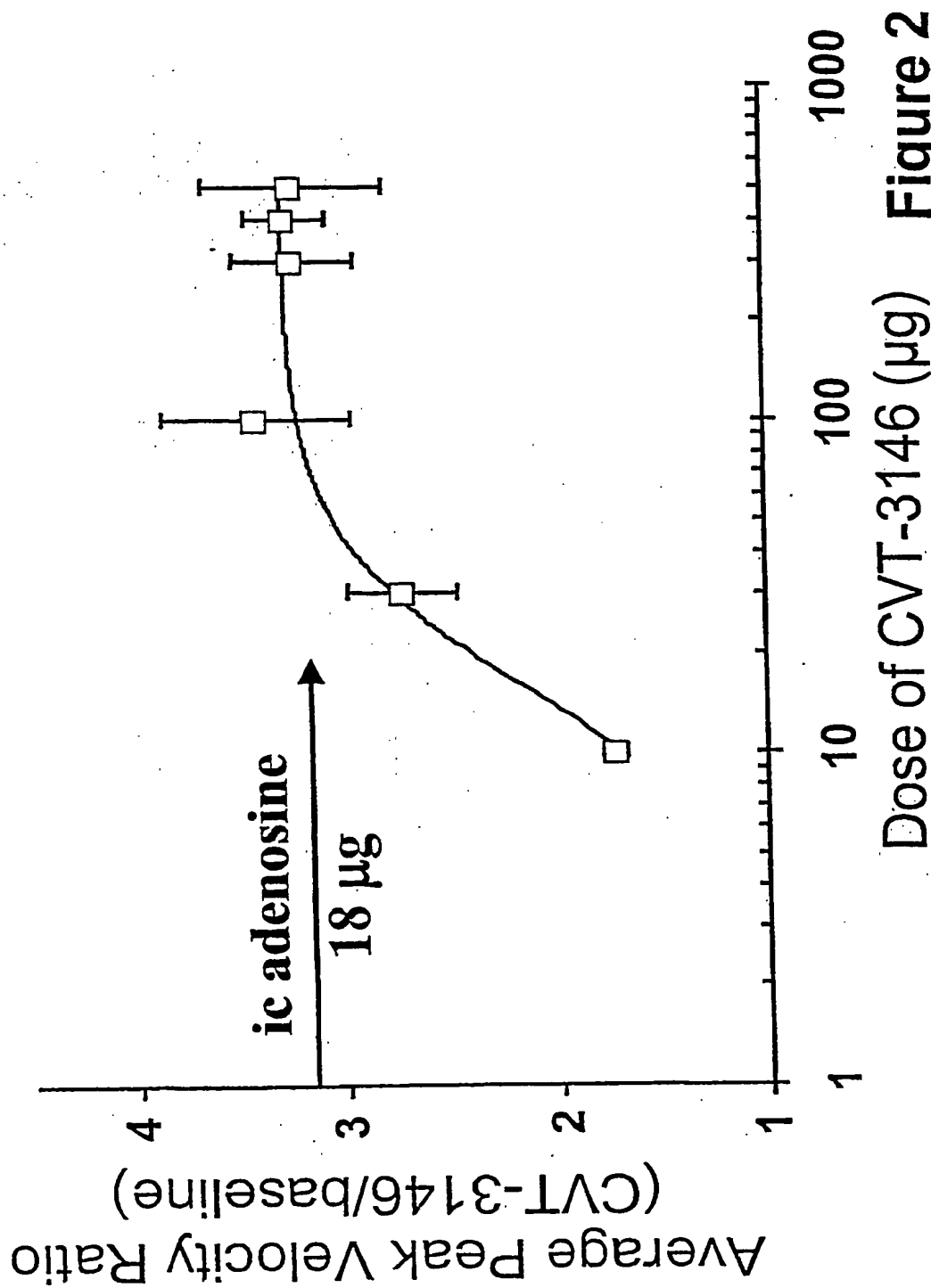
# Intracoronary Doppler Flow Velocity Profiles



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# Dose-Dependent Increase in Peak Flow Velocity Caused by CVT-3146



Dose of CVT-3146 (µg) Figure 2

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# CVT-3146 and Coronary Flow Velocity

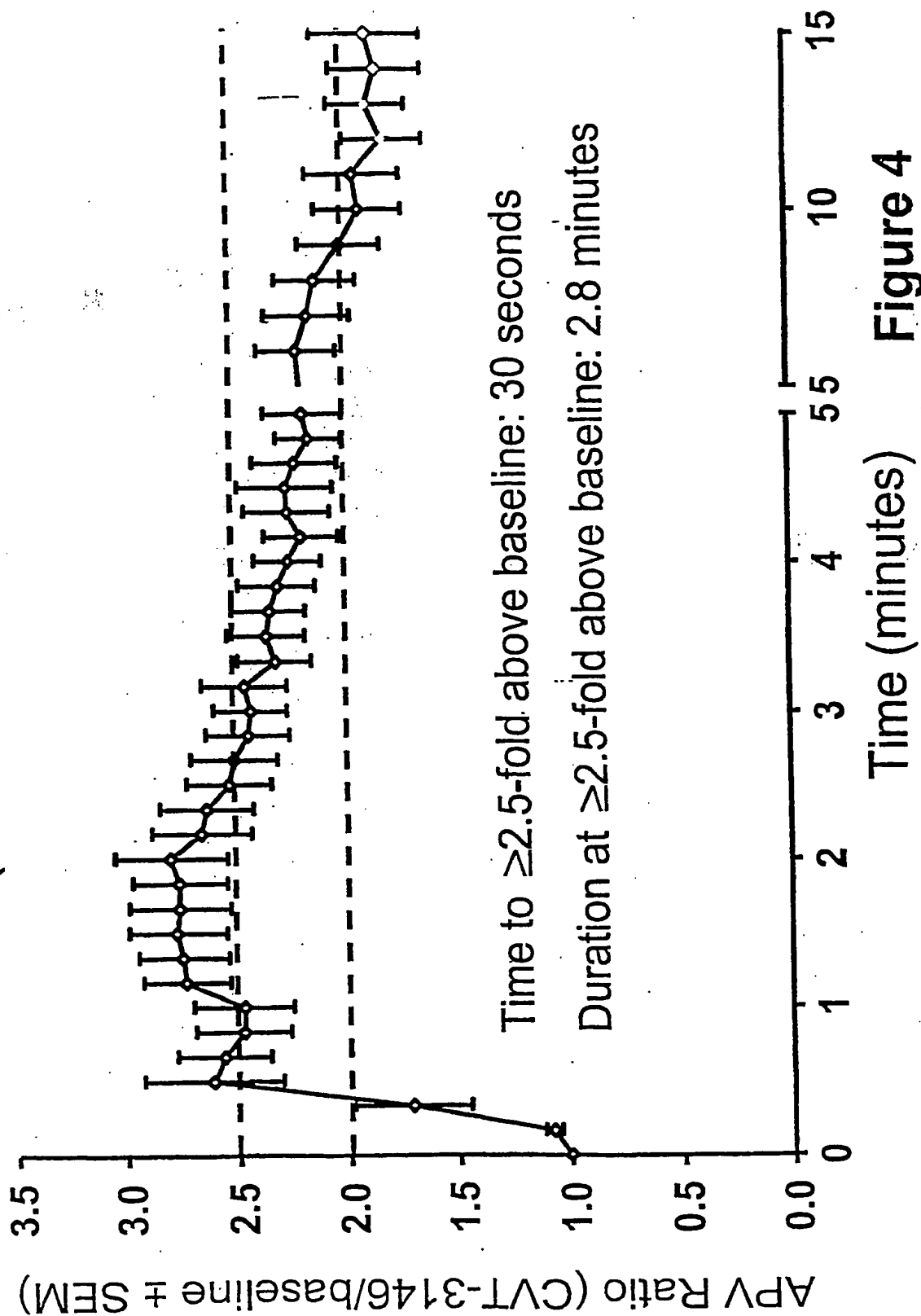
## *Duration of Effect:*

Duration $\geq 2.5$ Baseline	
Dose (n)	Mean $\pm$ SEM
10 $\mu\text{g}$ (4)	0
30 $\mu\text{g}$ (4)	0
100 $\mu\text{g}$ (3)	0.2 $\pm$ 0.2 minutes
300 $\mu\text{g}$ (4)	2.2 $\pm$ 1.3 minutes
400 $\mu\text{g}$ (8)	2.8 $\pm$ 0.8 minutes
500 $\mu\text{g}$ (4)	2.9 $\pm$ 1.3 minutes

Figure 3

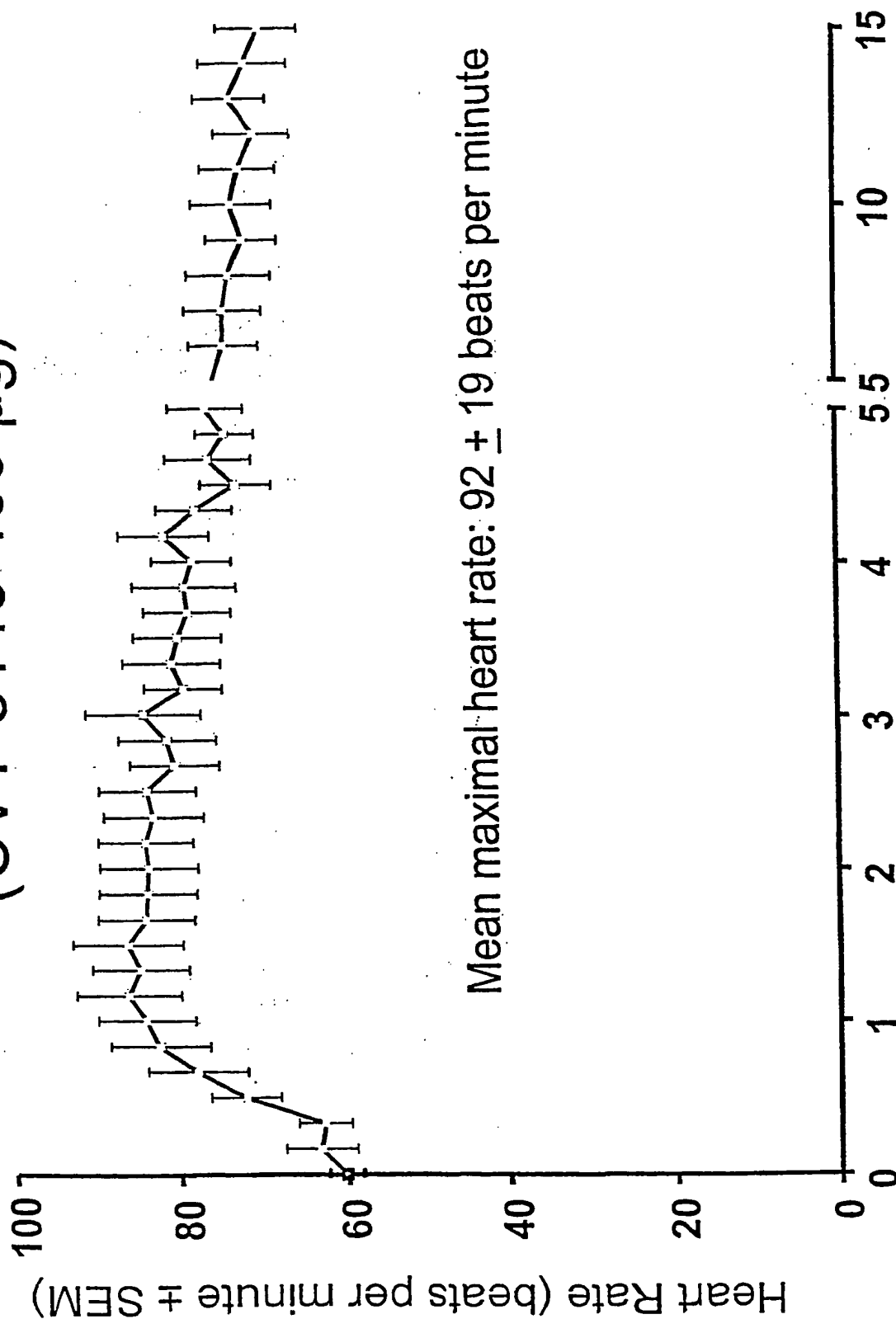
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# Time Course of APV Ratio (CVT-3146 400 $\mu$ g)

**Figure 4**

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# Time Course of Heart Rate (CVT-3146 400 $\mu$ g)



Time (minutes)      Figure 5

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# Time Course of Blood Pressure (CVT-3146 400 $\mu$ g)

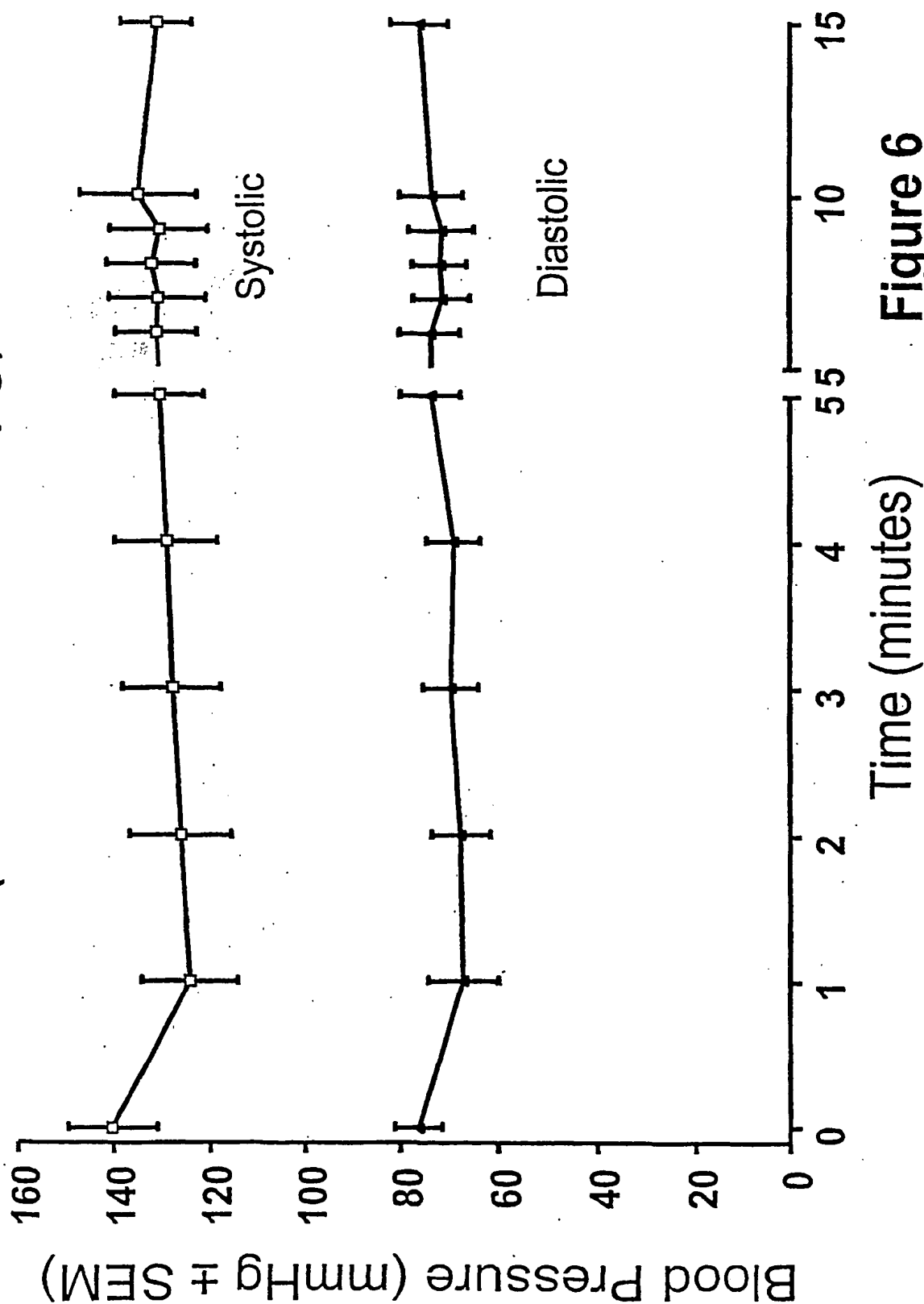


Figure 6

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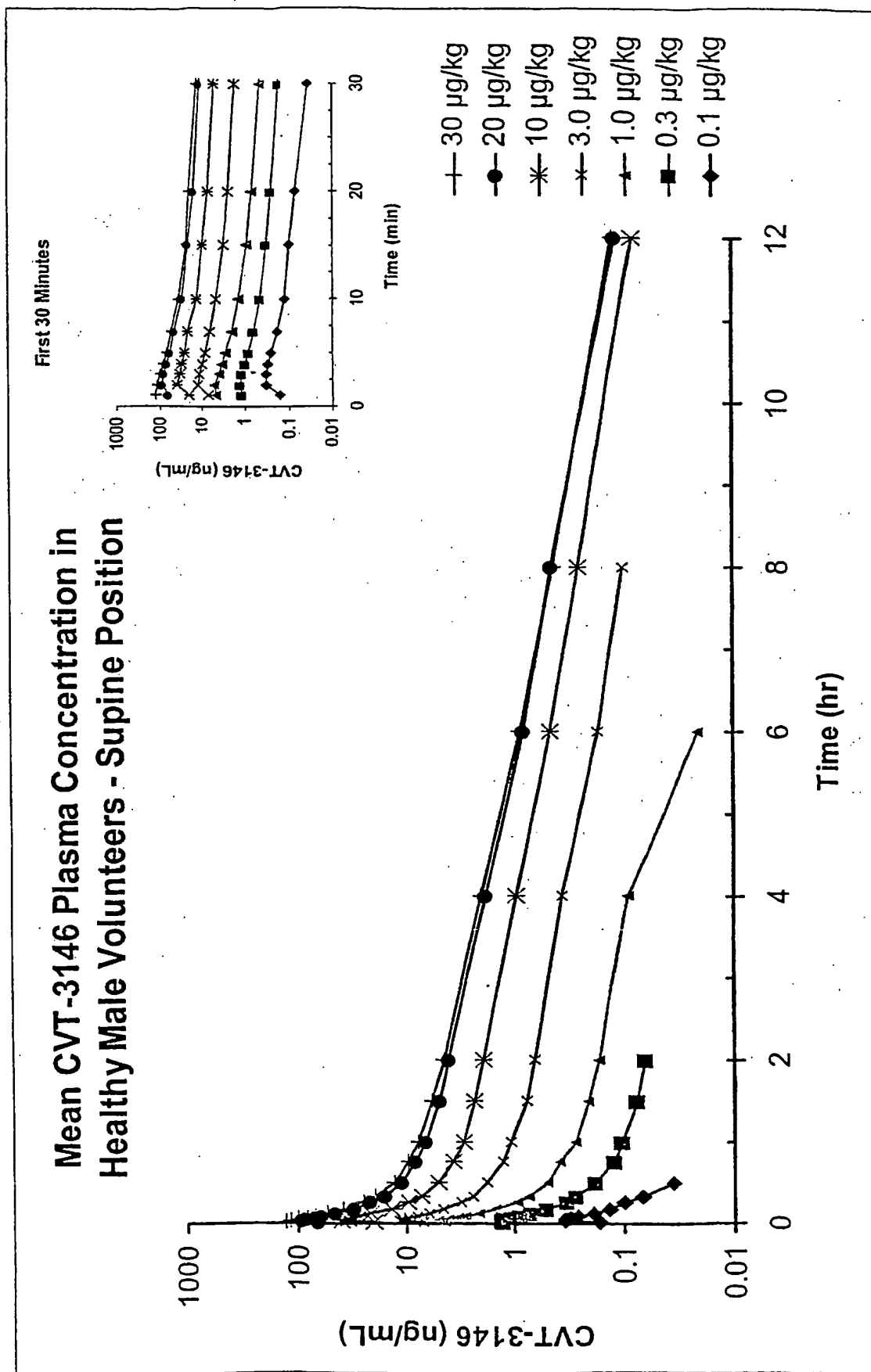
# All Drug-Related Adverse Events Were Mild and Transient

Adverse Event	All Doses 400 µg	
	(n = 36)	(n = 9)
chest discomfort	3	3
increased heart rate	3	1
hypotension	2	2
flushing	2	1
shortness of breath	2	0
funny taste in mouth	1	0
sensation in mouth; sinus, and chest	1	0
headache	1	0
tingling in hands	1	1
heart racing	1	1
bradycardia	1	1
lightheadedness	1	1
cough	1	0
nausea and vomiting	1	0

Figure 7

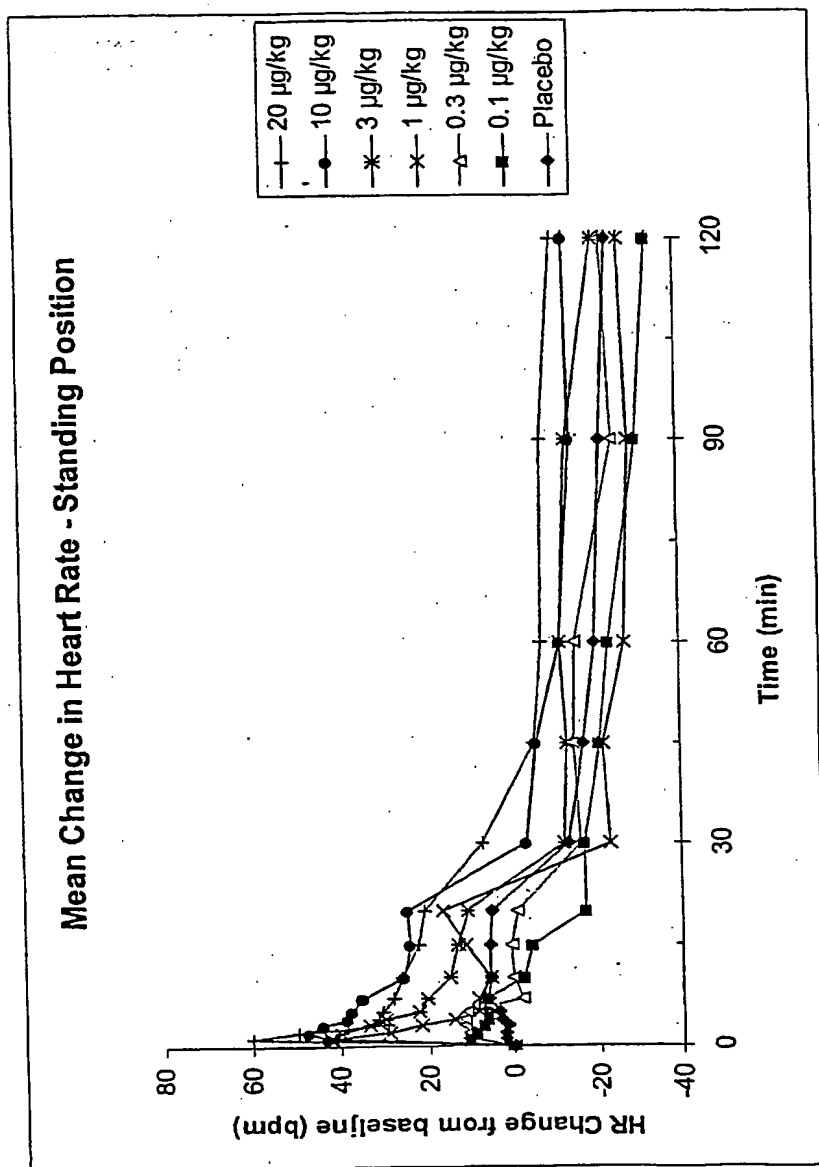
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Figure 8



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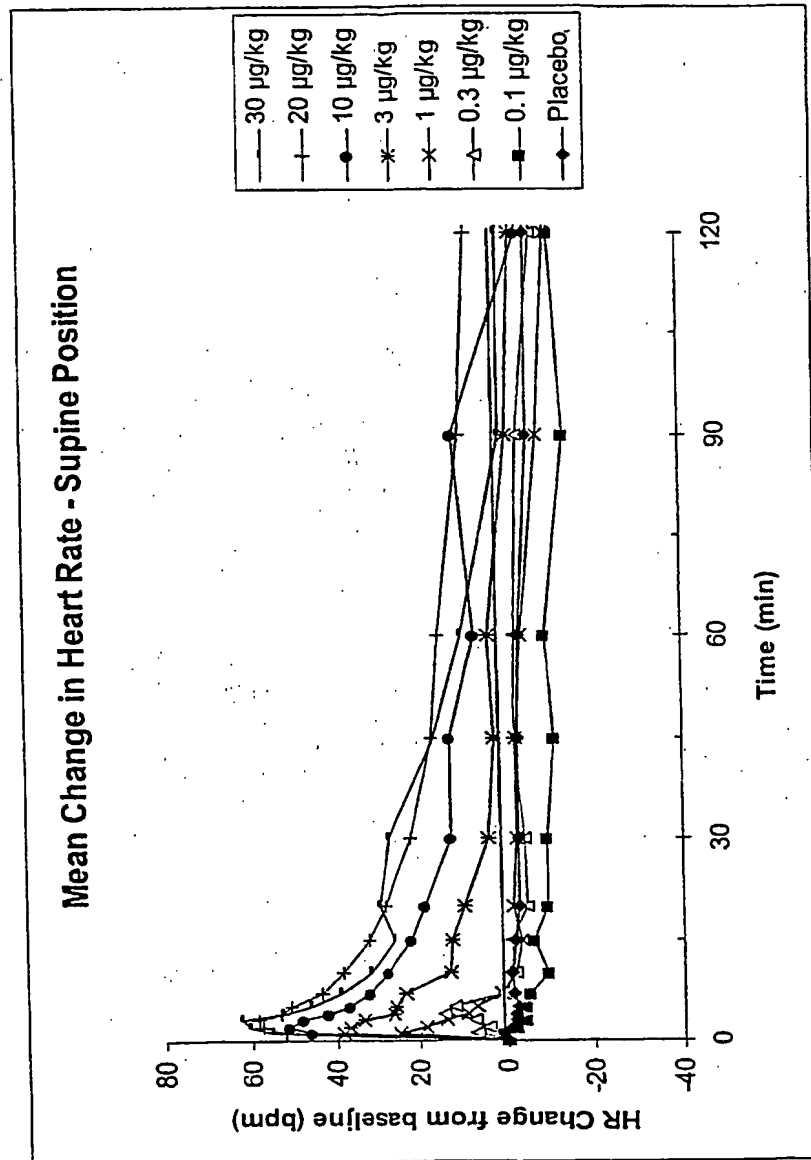
Figure 9



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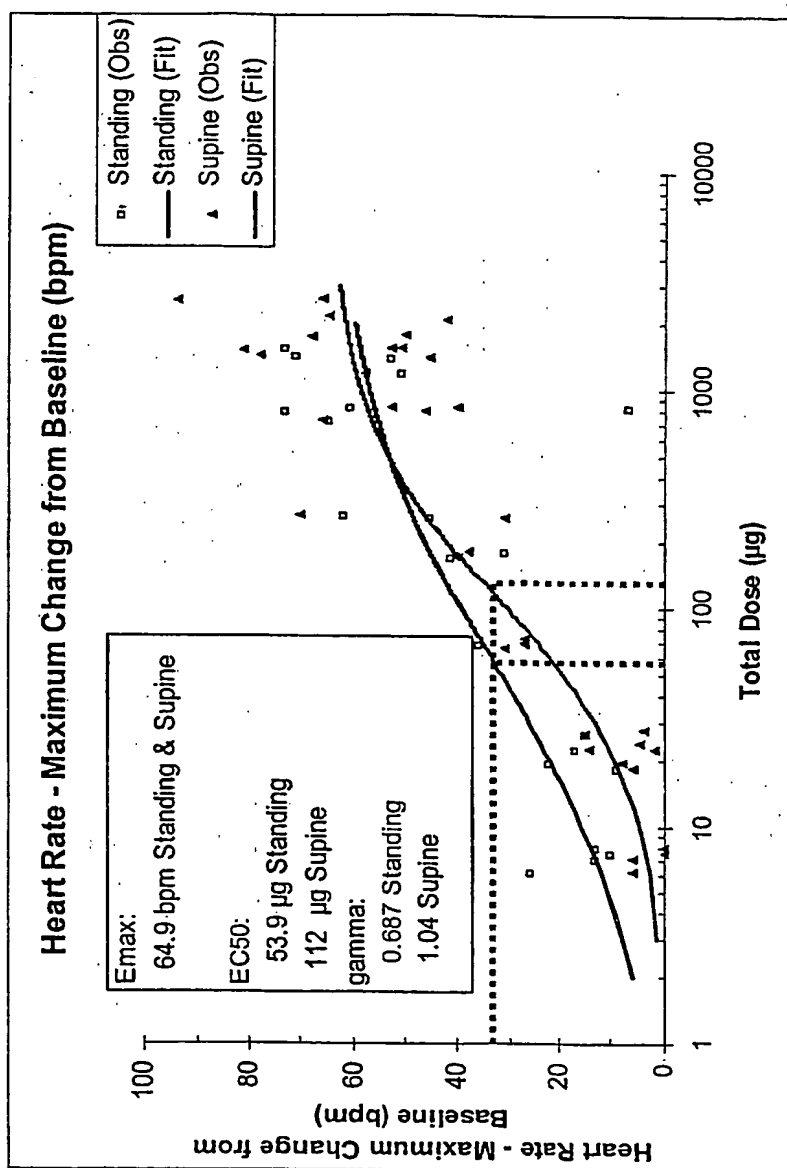


Figure 10



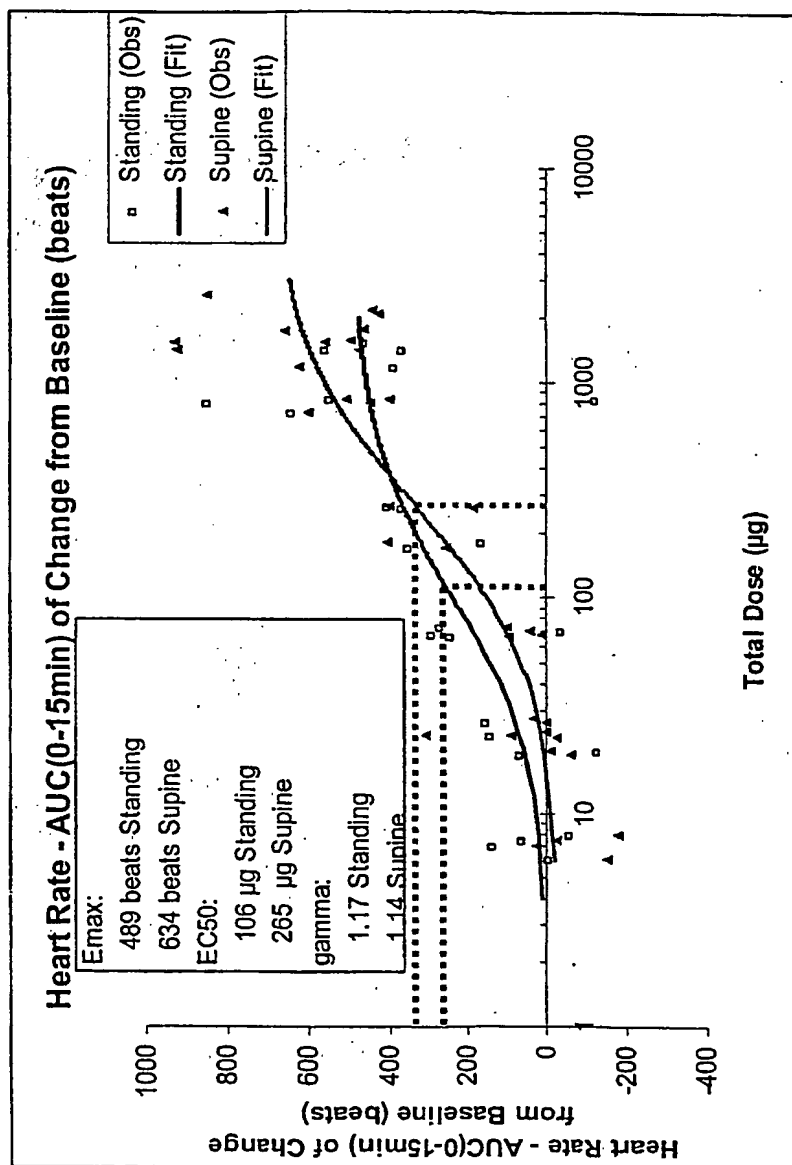
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Figure 11



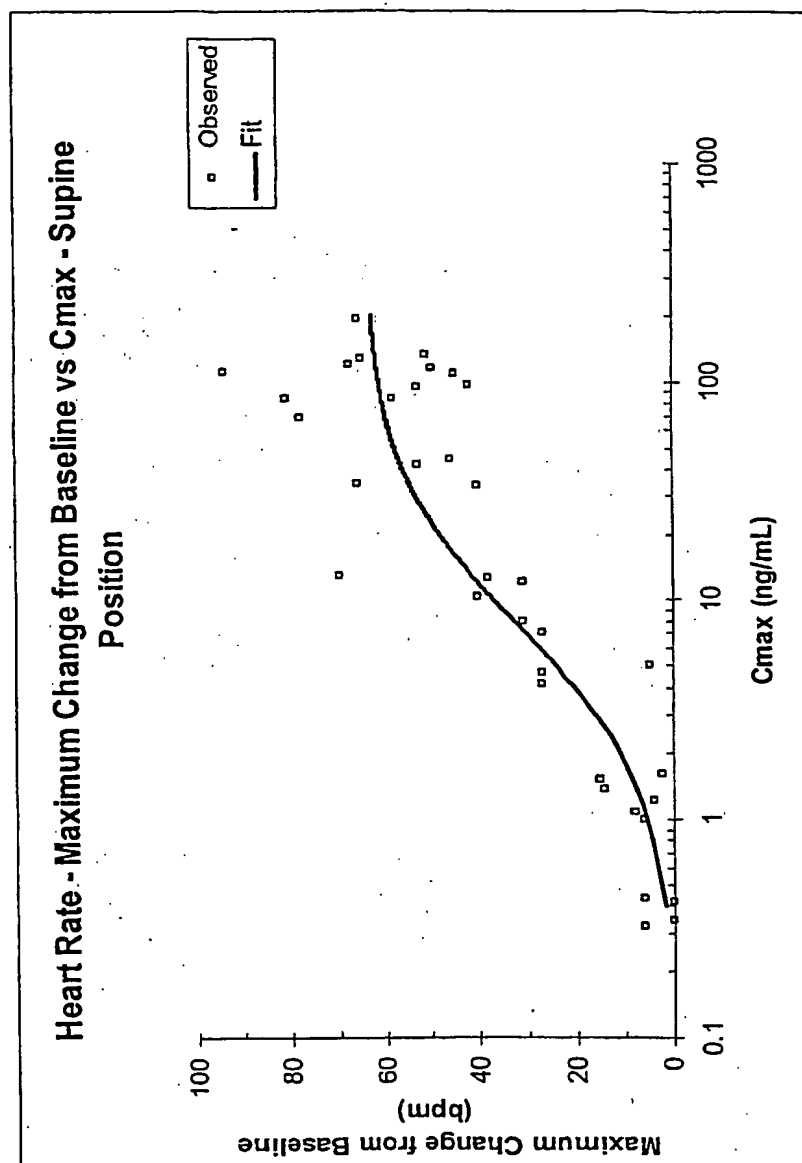
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Figure 12



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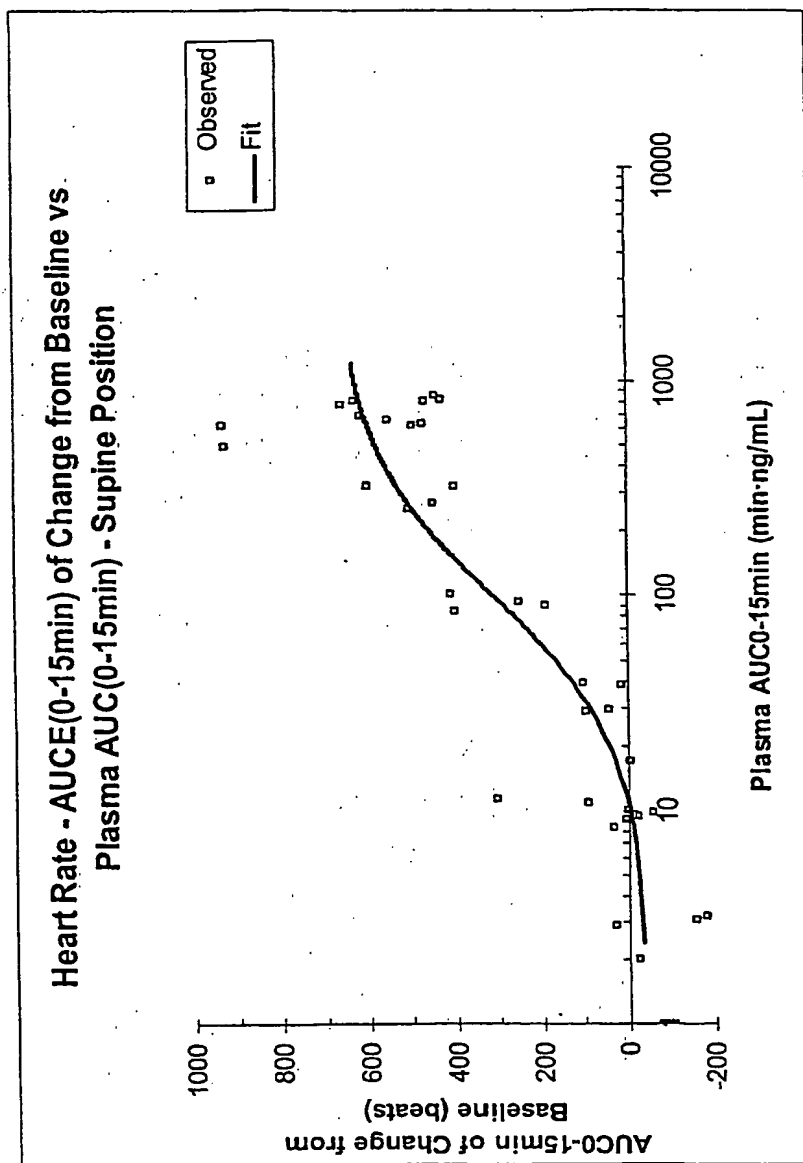
Figure 13



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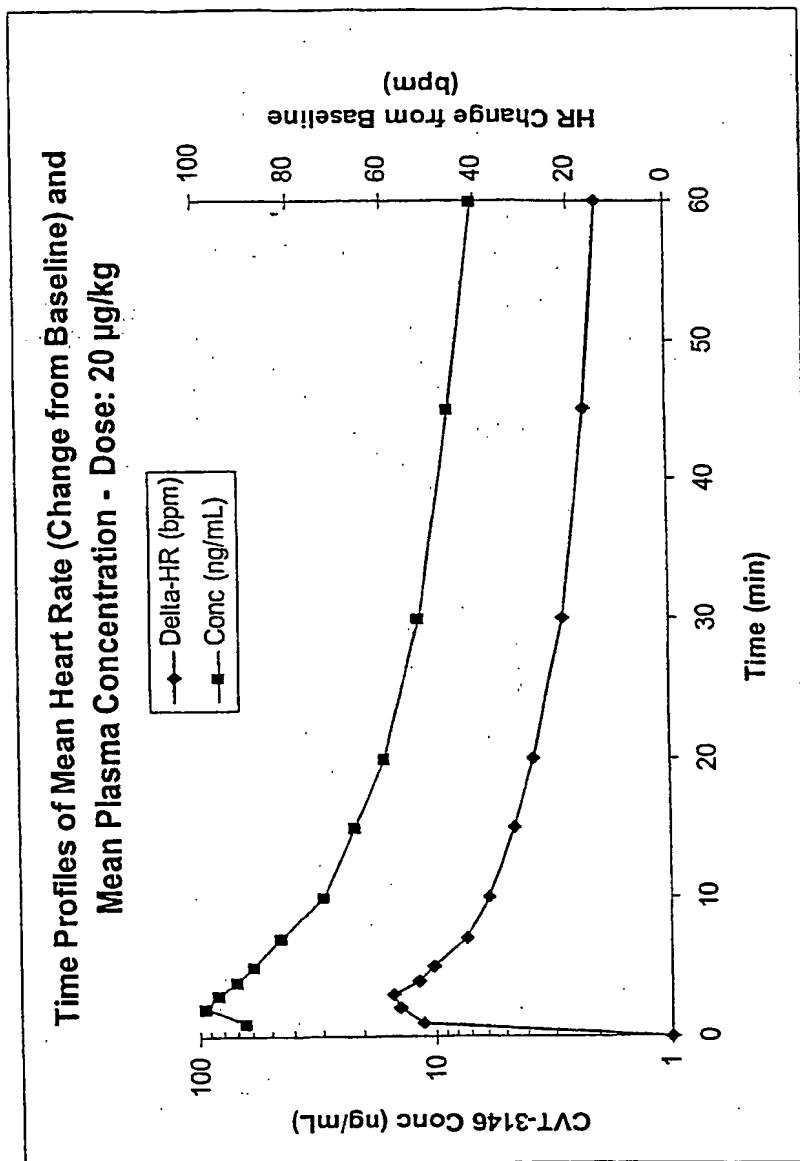


Figure 14

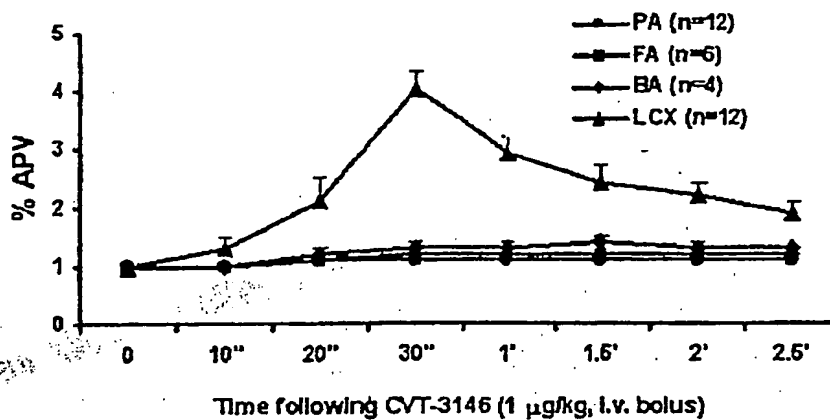
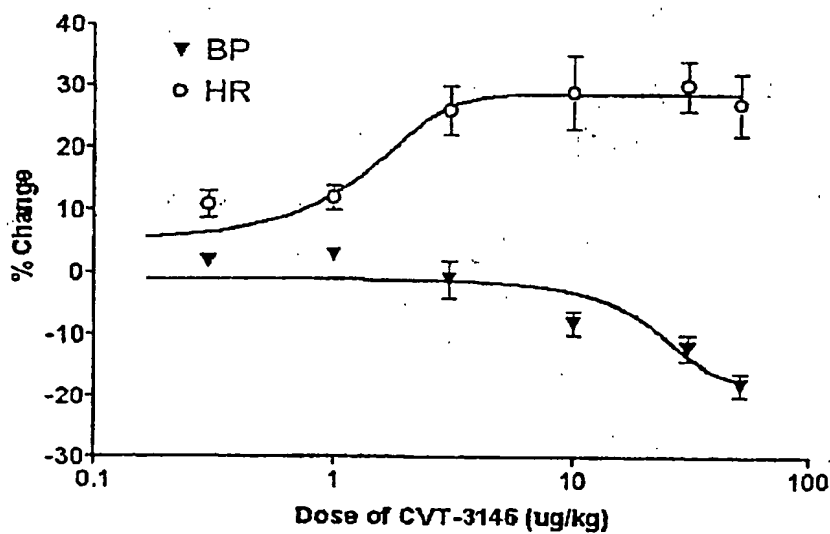


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Figure 15



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**Figure 16****Figure 17**

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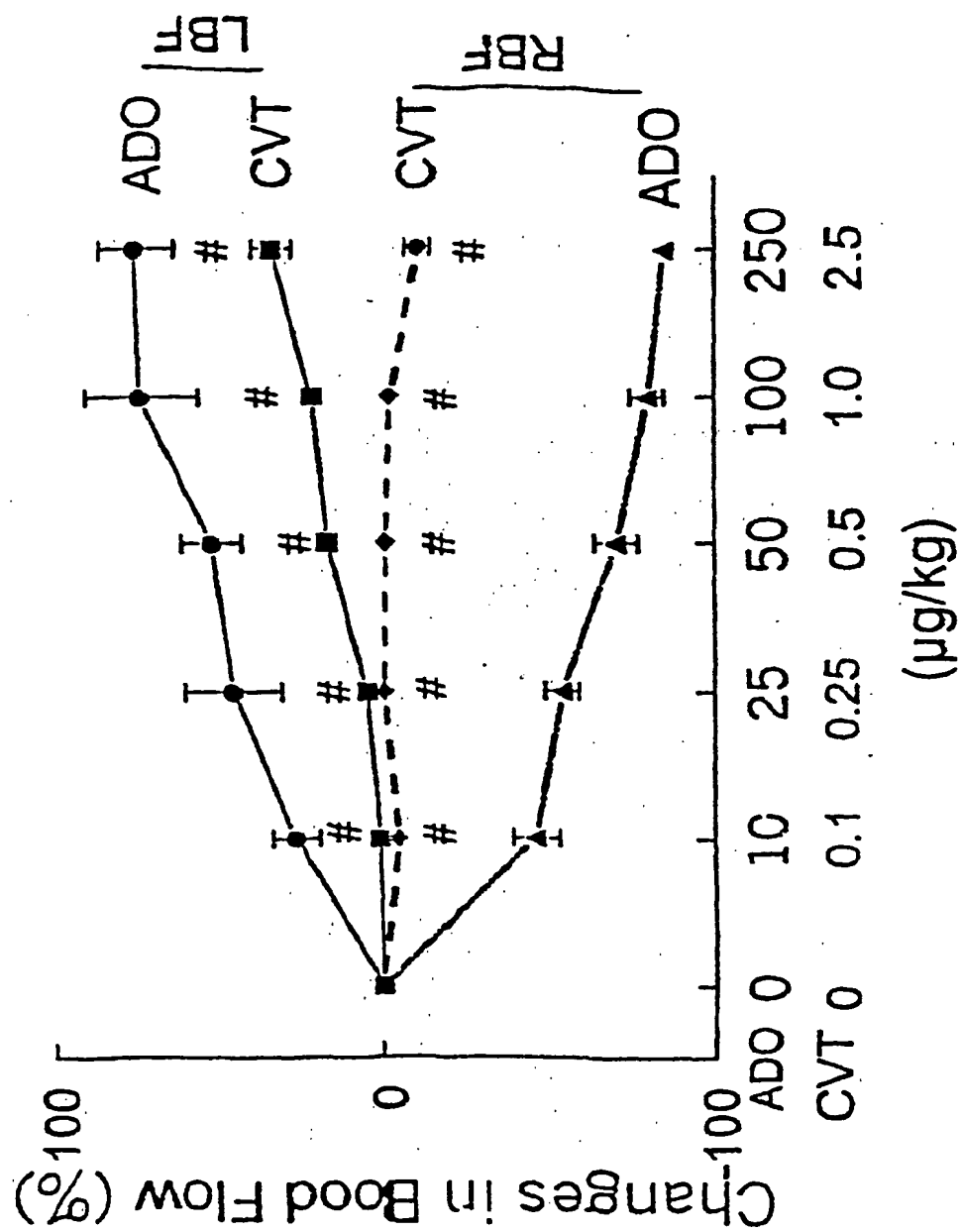


Figure 18

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## INTERNATIONAL SEARCH REPORT

International Application No.

PCT/US 03/23511

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 A61K31/7076 A61P7/00 A61P7/02 A61P9/00 A61P9/10  
A61P43/00

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 A61K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

WPI Data, EPO-Internal, PAJ, MEDLINE, BIOSIS, EMBASE, SCISEARCH, CHEM ABS Data

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 00 78778 A (CV THERAPEUTICS INC ;PALLE VENKATA P (US); ZABLOCKI JEFF A (US); E) 28 December 2000 (2000-12-28) page 2, line 5 - line 11 page 42, line 20 - line 27 Compound 18 page 23 claim 30 examples 6,7	1-30
X	US 6 403 567 B1 (PALLE VENKATA P ET AL) 11 June 2002 (2002-06-11) example 5 claim 11 column 1, paragraph 1	1-30
	-/--	



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

## \* Special categories of cited documents:

- \*A\* document defining the general state of the art which is not considered to be of particular relevance
- \*E\* earlier document but published on or after the international filing date
- \*L\* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- \*O\* document referring to an oral disclosure, use, exhibition or other means
- \*P\* document published prior to the international filing date but later than the priority date claimed

- \*T\* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- \*X\* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- \*Y\* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- \*&\* document member of the same patent family

Date of the actual completion of the international search

8 December 2003

Date of mailing of the international search report

18/12/2003

Name and mailing address of the ISA

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Authorized officer

Strack, E

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# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US 03/23511

## Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☒ Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:  
see FURTHER INFORMATION sheet PCT/ISA/210
2. ☒ Claims Nos.:  
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:  
see FURTHER INFORMATION sheet PCT/ISA/210
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

## Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this International application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

### Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

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# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 03/23511

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
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US 6026317	A	15-02-2000	NONE	

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